

Scientific Research and Essays

Volume 9 Number 10 30 May 2014
ISSN 1992-2248



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Review

Management and welfare needs of donkeys in the rural areas of Noushahro Feroze, Pakistan

Ghulam Murtaza Lochi², Muhammad Ghias Uddin Shah², Muhammad Shuaib Khan^{1,5*}, Jamil Ahmad Gandahi², Dildaar Husain Kalhorro², Sumera Ali Khan³, Farooq Alam⁴, Abdul Manan Khokar, Mubashir Hasan¹ and Abdul Haseeb Danish²

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Received 12 February, 2013; Accepted 11 November, 2013

In this study a concise review was provided, discussing the management of donkeys in the rural area of Naushahro Feroze Sindh Pakistan. In this area donkeys are commonly used for the transport ion of clay bricks, mud, and grain for grinding, manure from pens to field, crop harvests from fields to stores and market places, crop residues from fields to homesteads for storage, plowing and weeding, and it also as a means of transportation for people. Thus, the donkey is used more as a carting animal (transport) than for cultivation tasks (plowing and weeding). Need exists that, institutions should provide awareness for donkey care and health. There is also need to provide trainings to farmers on such subjects such as management, welfare, and healthcare etc.

Key words: Management, welfare, donkey, Naushahro Feroze, Pakistan.

INTRODUCTION

The domestication of plants and animals started about 11,000 years ago (Peter, 2005). The donkey or ass, *Equus africanus asinus* (Don and Reeder, 2005) was a domesticated member of the *Equidae* or horse family. Asses were first domesticated around 3000 BC or 4000 BC probably in Egypt or Mesopotamia (Nowak, 1999) and have spread around the world. They continue to fill important roles in many places today. Domestication of the donkey from the African wild ass transformed ancient transport systems in Africa and Asia and the organization of early cities and pastoral societies (Stine et al., 2008).

Agriculture, in Pakistan, registered the growth of 3.13% against 2.38% last year and livestock witnessed a marginally higher growth of 4.04% against the growth of 3.9% last year. (Anonymous 2010 to 2011). About 41 million donkeys were reported worldwide in 2006 (Waltraud et al., 2008) China has the highest with 11 million, followed by Pakistan, Ethiopia, and Mexico (Starkey and Starkey, 1997), Pakistan has around 4.7 million of donkeys (Anonymous, 2010 to 2011), where they were used principally as draught or pack animals. Grey, brown, and white were the common coat colors of

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Figure 1. Donkeys eating home wastes in Naushahro Feroze District.

local donkeys (Singh et al., 2005). The domestic donkeys of Pakistan like the donkeys in Africa traces its heritage to the wild asses found in Egypt, the Sudan, Somalia, and Ethiopia, namely *Equus asinus africanus* and *Equus asinus somaliensis* (Feseha et al., 1991). Sindh is the most populated province of Pakistan after Punjab, where people are mostly dependant on livestock and agriculture and use animals for their food and transportation. In villages of Sindh specially, in district Naushahro Feroze, donkeys are commonly used for the transport of bricks, mud and fire wood, grain for grinding, manure from pens to field, crop harvests from fields to storage and market places, crop residue from fields to homesteads for storage, plowing and weeding and also serve as transportation of peoples. In the outside edge of Naushahro Feroze, in the villages of Kandiaro, Hallani, Kotri Kabir, Bhirya city, Pacca Chang and periphery, donkeys are present in abundant number and involved in farming directly and indirectly.

DISCUSSION

Nutrition

In Sindh, villages are not developed as in Punjab province and other countries of Asia and of the world. There are no feeding values required for donkey in all over Sindh. Donkeys obtain most of their energy from structural carbohydrates. Some owners suggest that, a donkey needs to be fed only with straw, supplemented

with controlled grazing in the summer or hay in the winter. The variation may be acknowledged to management observations, and the sources of animals examined (Mirani et al., 2012).

A local owner does not care about the feeding of donkey. They are commonly vaulted in dirty areas of city where they fed on home food waste and drink stagnant water (Figure 1).

Donkey work load

Traditionally, animals like donkey and camels have been classified according to their function, for example, riding animals or pack type's animals (Shah et al., 2012). The donkeys are working almost many days in a year and about an average of 8 to 10 h a day. In donkey cart, they work near to 11 to 12 h. The distance covered by the donkeys varied from 10 to 40 km at 2 to 5 km/h as a pack and 8 to 16 km/h as cart. They play a major role in the economy of villagers, mostly in transportation from one village to another village.

Donkeys are usually reared by poor people and work in harsh environments for the fulfillment of their basic needs through transportation of goods and peoples, in some places of Naushahro Feroze, the average price of this kind of work is of 100 PKR for 2 km for loading on donkey cart and this money also depend upon load, making their welfare cause for concern due to economic pressures. Donkeys carried 60 to 100 kg weight as a pack and 100 to 500 kg in cart (Singh et al., 2005), as depicted in



Figure 2. Typical loading on donkey in Kandiaro.

Figure 2.

HOUSING AND MANAGEMENT OF DONKEYS IN VILLAGES

Housing and stabling

There was a poor housing system for donkey. Owners have small stables for their animals, as seen in Kotri Kabir, Bahlani, Halani, Kandiaro, Machur, Bhirya city and their vicinity. Proper cleaned mangers are usually lacking and, if present, are usually made up of clay. Small buckets are used for their drinking water. Stables were not seen clean and ventilated, and were mostly too wet due to manure and urine (Khan et al., 2013). Stables were usually open in all seasons even in winter freezing nights and hot summer days.

Cruelty on donkeys

Donkeys are more likely than mules or horses to demonstrate avoidance or aggressive behavior towards an observer, while horses were most likely to make a friendly approach (Pritchard et al., 2005). Owners apply harsh punishments to their donkeys, extra loading, improper uses of old saddle, which are barely supportable. They usually punish cruelly with sticks.

Lameness is commonly seen accompanied with rough skin coat and different types of wounds. Most of the donkey's owners do not care for the donkey's body coat or tropical and saddle wounds (Khan et al., 2013).

Needs of animal welfare

Unfortunately there are not any animal welfare organizations and Non Governmental Organizations (NGO's) in the District population of donkeys and there is no special animal welfare teams working to treat infected or injured donkeys. Owners leave their donkeys when they are highly injured or suffering from lameness and those donkeys freely walks in over populated district areas and cities. The threat of zoonotic diseases remains a problem all year over. Due to unawareness and lack of knowledge about animal welfare, people use highly injured and diseased animals in load and traction. It is also seen that, young donkeys are prematurely used, in support of adult animal in donkey carts, when they bear extra load.

CONCLUSIONS AND SUGGESTIONS

Donkeys are the mainly ignored and disregarded animals in Pakistan. (Khan et al., 2013) Donkeys are less ignored animal in Sindh province due to unawareness. Owners

ignore the importance of welfare and management of donkeys.

A protocol should be developed to assess the welfare of working equines specially, donkeys, in urban and rural areas, using express observation of physical condition and welfare parameters. There is an urgent need to activate NGOs and animal welfare organizations in the remote districts of Pakistan, to design special small mobile equines hospital units which can provide both treatment and also collect data for injured, lame and retired equines. These units also can provide training for donkey owners and young veterinary professionals on such subjects as welfare and management.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Secure anycast routing in wireless mesh networks

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Received 25 May, 2011; Accepted 16 August, 2011

Wireless Mesh Networks (WMNs) are the hybrid networks having fixed infrastructure of gateways to provide the Internet connectivity to its fixed or mobile clients. It has redundant links to provide reliable communication. Anycast is an important service for the group communication. Field based routing is getting popularity due to its robustness and simplicity. In this paper, we have studies on the security issues for the anycast service based upon the field based routing. The scheme has been studied to eliminate the effects of the external intruders and also against the internal selfish nodes. The modified secure field based routing strategies have been proposed to safeguard the legitimate traffic from these external and internal intruders. The simulation results in OMNet++ simulator shows that the proposed techniques outperform the normal routing mechanisms.

Key words: Anycast, field base routing, security.

INTRODUCTION

Wireless Mesh Networks (WMN) is a multi-hop wireless networks like MANETs, the change in structure and behavior of mesh network make the routing mechanism relatively different as compared to other networks (Akyildiz et al., 2005; Bruno et al., 2005). A mesh network consists of mesh routers and mesh client. Wireless mesh network is a multihop network so connectivity is not a big issue as compared to other networks. Various nodes perform two way communications to facilitate the reliable communication. The devices are equipped with multi channel and have the capability to handle multiple network connections (Yling et al., 2005). As the mesh network becomes small and cheap, it will easily be incorporated with a variety of devices in our everyday lives (Lenders et al., 2006). Anycast is a service which can increase service availability. It is a special type of routing in which a packet transmits to any node among a group. This single destination node may be chosen by

different types of parameters like number of hops, delay or other metrics. There are set of anycast destination nodes. Anycast is used to get the service from any nearest server without considering the particular one (Ling et al., 2009). Field based routing is widely adopted due to its robustness and simplicity. We have also used the field based routing for the anycast routing in wireless mesh networks. Filed based routing is prone to various internal and external intruders' attacks. As it depends solely on a routing filed; any intruder may mislead the nodes towards itself by introducing the maximum routing filed wrongly. Wired network uses traditional approaches to achieve privacy like cryptography (Chaum et al., 1981; Reed et al., 1998; Dingedine et al., 2004) or redundancy to achieve communication end privacy (Reiter and Rubin, 1998).

The traditional approaches (Xiaoxin et al., 2009) cannot be directly applied to field base routing mechanism. That

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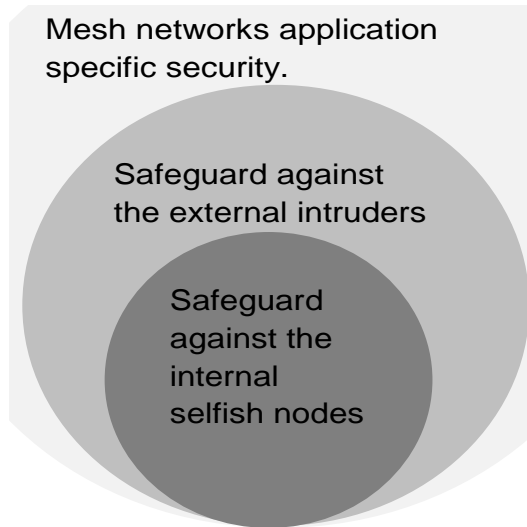


Figure 1. Wireless mesh network security architecture.

is why there is need to propose the security measures to secure the field based routing for anycast routing in wireless mesh networks.

Related work

Mesh network is a multihop network in which very node can communicate with each other using multi hops. To route the packet securely in a mesh network, every node should be well secured and route the packet securely from source to destination. To ensure that every node in the network forward the message correctly, a mechanism is needed to ensure the authenticity of a node. Literature discusses a lot about security issues in multihop wireless mesh network. In Baumann et al. (2007), authors discussed routing in large scale wireless mesh network using temperature fields. As this technique uses field based routing so need more security and authenticity of node. Sangsu et al. (2009) proposed a load balancing mechanism for any cast wireless mesh network but not discusses about the security issues related to these type of network. Ling et al. (2009) and Song and Xia (2009) discusses about any cast routing in wireless mesh network using multi gateways. As this network route packet efficiently due to any casting so need more security and reliability, yet no security mechanism is developed for these types of network. Pal and Nasipuri (2010) discuss 'quality aware anycast routing protocol' for wireless mesh network, they proposes a heuristic for route selection that tries to perform gateway and route selection to minimize interference. This study also does not focus on security issues related to this anycast routing mechanism. Anycast routing in mesh network need a lot of focus regarding security. Lebbe et al. (2007) proposes a mechanism to detect the danger in mesh network. They identify and classify the network dangers

and take necessary actions to overcome those dangers. For the classification task, they apply self-organizing maps (SOMs) as the classifier to classify the danger levels in mesh network. Their study shows the danger level but discuss the counter measure and how to safe the network from different internal and external attacks. In Glass et al. (2009), authors discussed an intrusion detection mechanism that identifies man-in-the-middle and wormhole attacks against wireless mesh networks by external adversaries. Beside these, various other authors have discussed the security in such environments as this (Scarlata et al., 2001; Stephen et al., 2009).

Atif et al. (2009) discusses about 'secure filed' based routing in 'mesh network' but this technique only secures the network from external attacks. In this approach the network assumes all the nodes to be the registered members of the network and only detect the nodes coming from outside the network and shows that they are not part of the network. The nodes that are not part of the network, the mechanism declares those as a corrupt nodes and never route the traffic towards these nodes. Muhaya et al. (2010) discussed about selfish node detection as internal intruders and proposes a mechanism to identify these types of nodes.

Marti et al. (2000) proposed a mechanism watchdog to solve the problem of how to monitor the forwarding of data message. This mechanism only works for single hop network and not covers the multihop network. Also it discusses how to protect the data message but not discuss how to detect the corrupt nodes in the network. The secure routing protocol for example 'secure DSR' (Kargl et al., 2005), Ariadne (Hu et al., 2002), ARAN (Sanzgiri et al., 2002) and 'secure AODV' (Zapata, 2002) provide secure mechanism to maintain in which no nodes will come as an intruder. All these types of algorithms not detect the misbehavior of internal nodes.

NETWORK MODEL

Mesh network faces a lot of security threats like internal, external, application security and different types of group head attacks. External attacks are launched by the external intruders hijacking the sessions and capture the data to launch the active and passive attacks. Internal attacks are launched by the internal legitimate selfish clients to mislead the routing traffic and to launch various attacks. In this paper, we have covered all the aspects of external and internal attacks. The detailed analysis has been presented for anycast traffic type. Moreover some results have been confirmed for multimedia traffic as well.

An anycast scenario of mesh network is proposed showing some nodes connected in a mesh style having a gateway and routers. All nodes in a network act as a router.

Security architecture

The wireless mesh network security architecture is given in Figure 1.

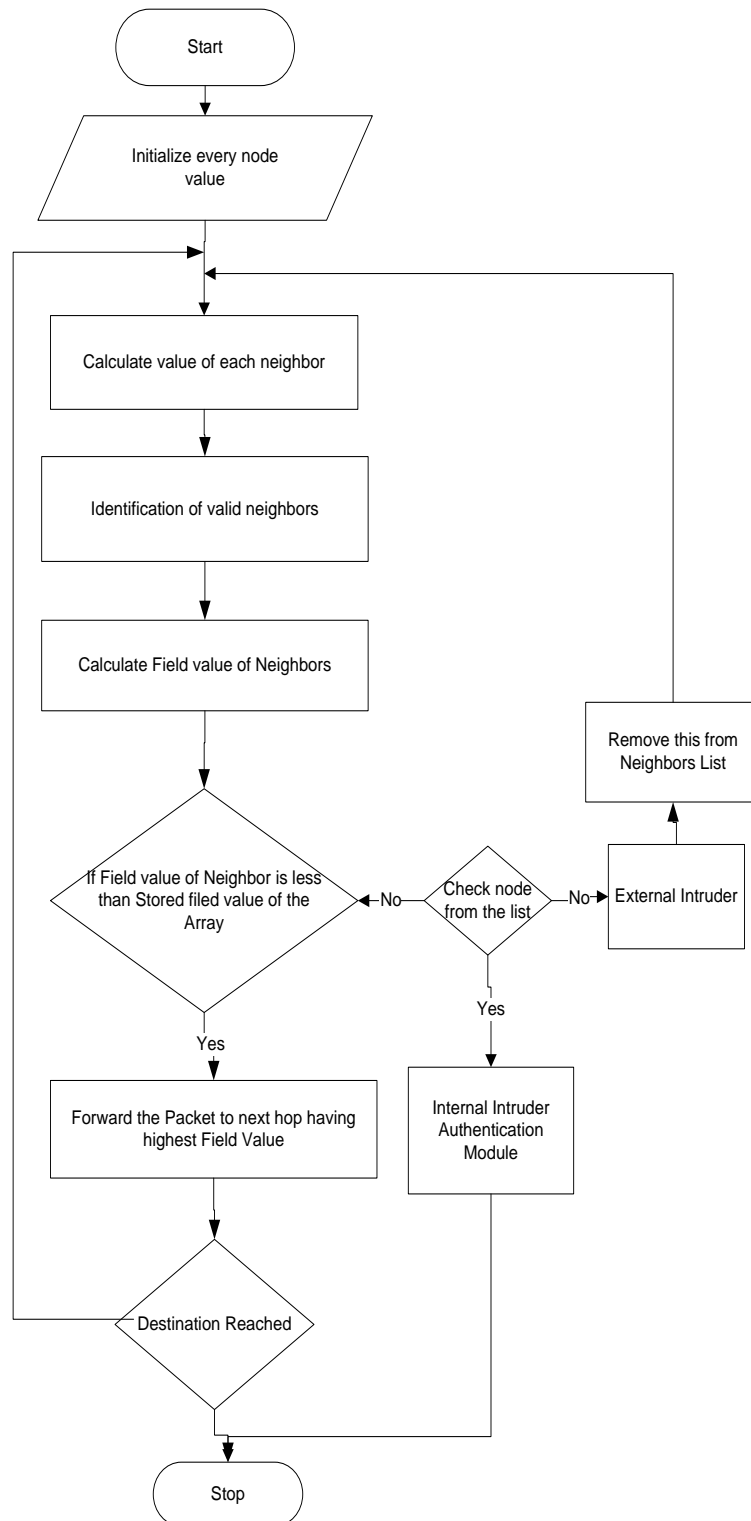


Figure 2. Flowchart for detecting external attacks.

Flow charts

To mitigate various external and internal attacks, detailed Flow charts are given in Figures 2 and 3 respectively.

Figure 2 shows the flow chart of detecting the external attacks on mesh network. As each node calculates their field value and share this value with directly connected neighbors; every node calculates its value from their

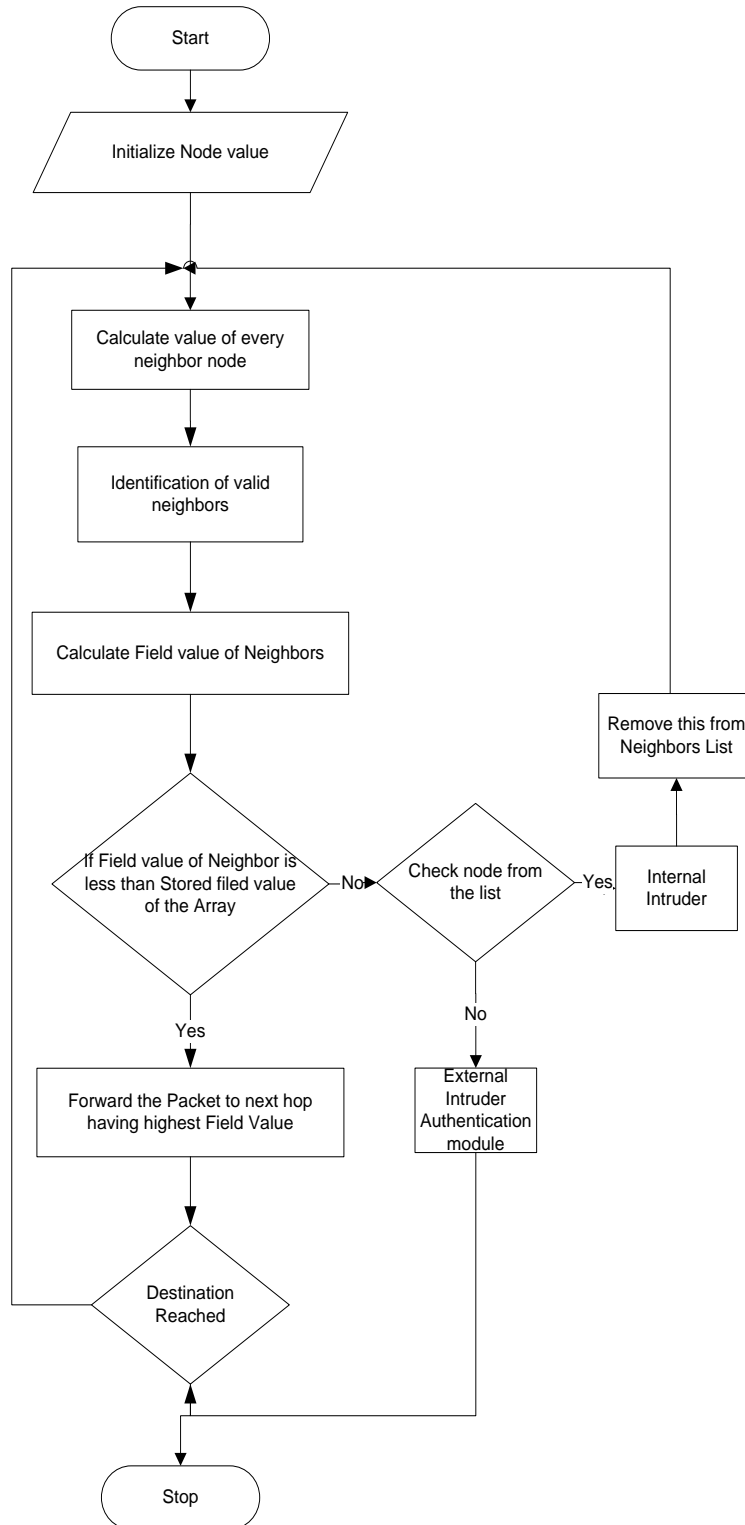


Figure 3. Flowchart for detecting internal attacks.

neighbors and performs routing on the basis of these values. If the value of neighbors is less than the node value, now it will be authenticated as an internal or

external intruder. The node first check from the list if it does not exists as registered and behaves like a normal node and advertises its value to be maximum so that

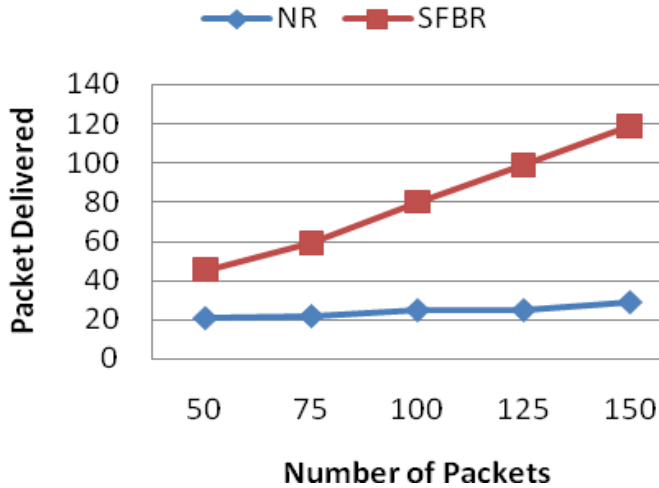


Figure 4. Packets delivery ratio by intruders at various level.

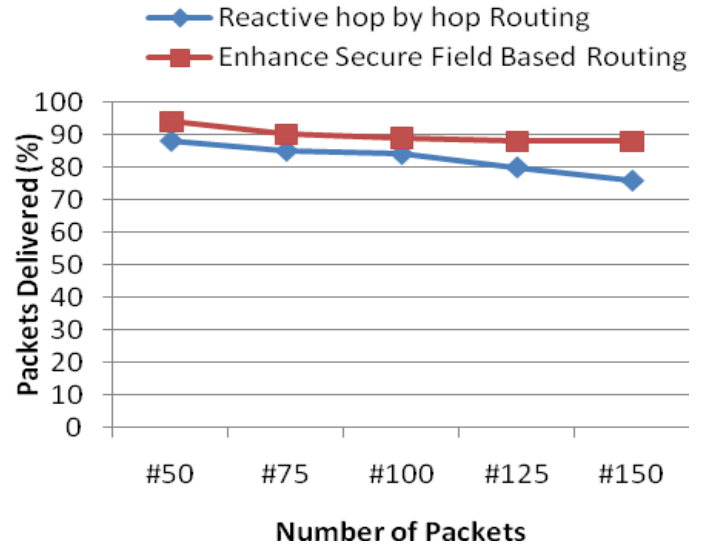


Figure 6. ESFBR vs reactive hop by hop routing.

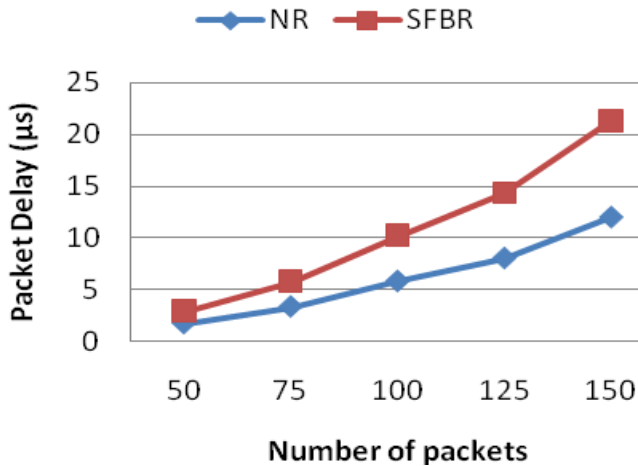


Figure 5. Total packet delay time (µs).

routing always takes place by this node, the node never forwards the packet and declares it as an external intruder. Figure 3 shows the flow chart of detecting the internal attacks on mesh network. As each node calculates their field value and share this value with directly connected neighbors. Every node calculates its value from their neighbors and performs routing on the basis of these values. If the value of neighbors is less than the node value, now it will be authenticated as an internal or external intruder. The node first check from the list if it does not exist as a registered node and still behaves like an intruder, the node never forwards the packet and declare it as an intruder.

PERFORMANCE EVALUATION

The performance of secure field based routing (SFBR) is measured using the OMNet++ simulator. The results

shown in Figure 4 explain the packet delivery of packets at different samples of packets. This graph shows a comparison between secure and normal routing packet delivery. The secure mechanism shows greater packet delivery ratio as compared to normal routing mechanism because it minimizes the probability of dropping the packets by the possible external intruders. Figure 5 shows the delay of both the normal and secure routing. As secure field based routing follow alternates path in case of any intruder so faces some delay as compared to normal routing mechanism, but normal routing compromises efficiency and suffer delay in packet delivery. After performing the secure field based routing, the enhanced secure routing mechanism (ESFBR) is used to route the packet efficiently. ESFBR uses a secure array to maintain the field value of every node, this array help in routing the packets securely. ESFBR is compared with many protocols already working. Figure 6 shows the comparison between ‘reactive hop’ by hop and ESFBR routing mechanism. ESFBR protocol experiences better packet delivery ratio as compared to ‘reactive hop’ by hop routing. Figure 7 shows the comparison of ‘proactive field’ based routing and ESFBR. ESFBR faces a better packet delivery ratio at less number of packets but as number of packets increases the ESFBR shows same number of packets delivery as in proactive field based routing mechanism. Figure 8 shows the delivery ratio of wireless mesh gateway routing and ESFBR. ESFBR is efficient at less number of packets but wireless mesh gateway routing shows better ratio at higher number of packets. Figure 9 depicts the comparison between wireless mesh gateway routing enhanced and ESFBR shows the best performance of ESFBR at lower number of packets, but as the packets increases, both protocols shows the same type of behavior. We have also performed some test for the multimedia traffic using field based routing in wireless

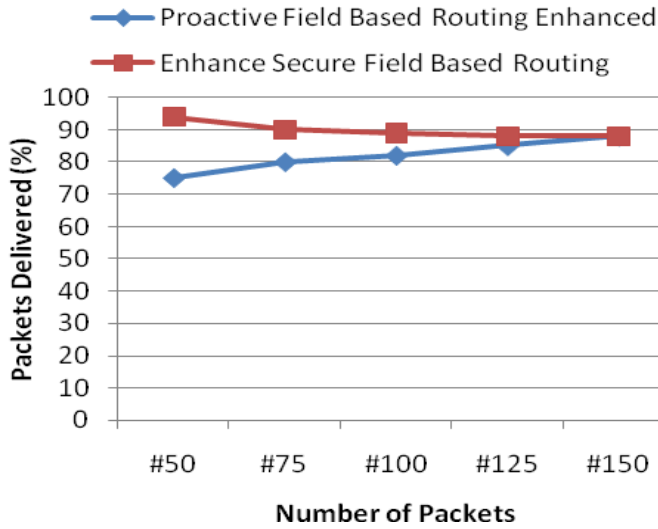


Figure 7. ESFBR vs proactive field based routing.

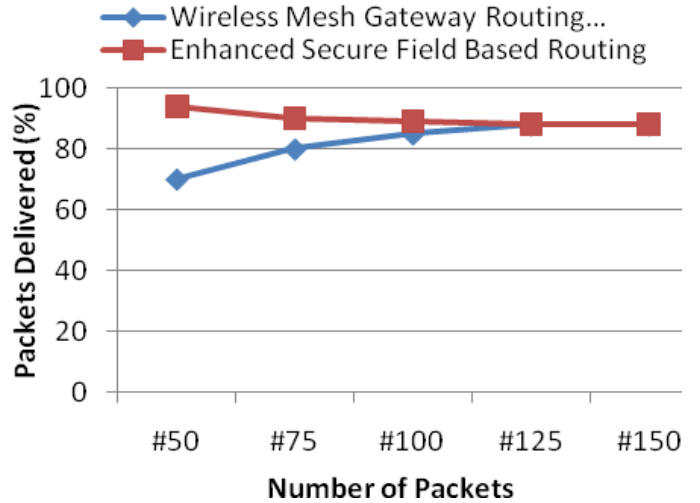


Figure 9. ESFBR vs wireless mesh gateway routing enhanced.

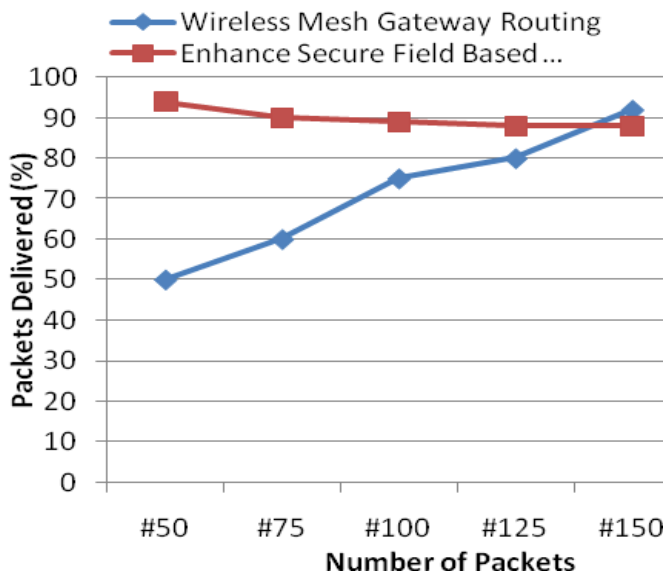


Figure 8. ESFBR vs wireless mesh gateway routing.

mesh networks. As multimedia traffic may consists of different length of packets.

The study considers different size of multimedia packet and studying the delay occurs due to change in the packet size. The behavior shows that as the multimedia packet increases in size, the delay increase. The results are shown in Figure 10. Figure 11 shows the comparison of secure and unsecure multimedia routing. Most of the traffic does not reach the destination due to unauthenticated nodes present in the network. The earlier paper proposed a secure multimedia routing and compares the results with unsecure routing in which

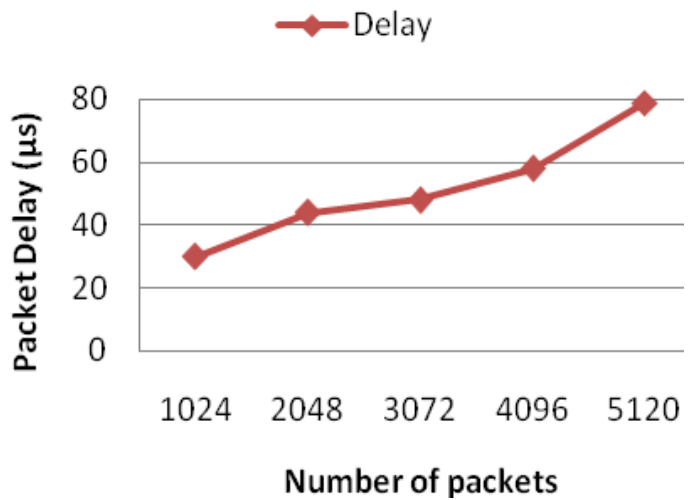


Figure 10. Delay in multimedia traffic.

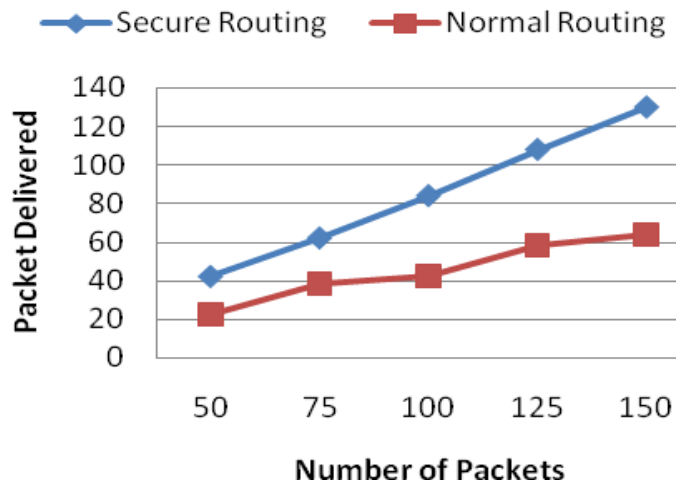


Figure 11. Packets delivery ratio with and without intruders.

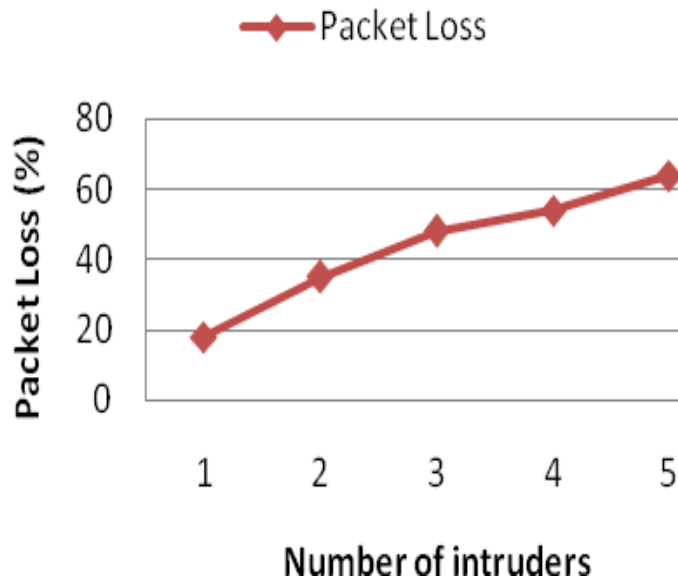


Figure 12. Packet loss due to change in number of intruders.

some intruders were present in the network. These intruders drop most of the packets and almost half of the traffic does not reach the destination. In secure routing the authentication mechanism first authenticates every node and then delivers the packet to the authenticated node. Figure 12 shows the packet loss due to change in number of intruders at different levels to analyze the behavior of the network.

CONCLUDING REMARKS AND FUTURE WORK

Field based routing in wireless mesh networks has numerous security issues. In this paper we have studied the anycast routing and the multimedia traffic based upon the field based routing. A novel approach is adopted to mitigate the external and internal intruder's attacks. Extensive simulation results revealed that the proposed techniques are secure and improve the system reliability while it keeps the best features of the field based routing.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Patterns of premarital childbearing among unmarried female youths in sub-Saharan Africa: Evidence from demographic health survey

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Received 17 May, 2013; Accepted 31 May, 2013

Premarital childbearing (PC) among young women remains a problem in Africa. Victims are often stigmatized, neglected and their socio-economic advancement in life is compromised. There is dearth of information on patterns of PC among unmarried female youths (UFY) in sub-Saharan Africa. The objectives of the study are to explore the patterns and differentials in the levels of PC in sub-Saharan Africa. It also identifies the factors that might account for high cases of PC in the region. The study used DHS dataset for Nigeria, Senegal, Rwanda, Malawi, Congo DR and Namibia. Bivariate and multivariate analyses were used to examine association between the socioeconomic factors and PC among UFY (15 to 24 years). The prevalence of PC was found to be highest in Namibia (25.5%) and least in Nigeria (4.8%). PC was more prominent among women with no formal education in Namibia (54.4%), Rwanda (16.5%) and Congo DR (7.9%). In Malawi, 4.5 and 78.0% of UFY had their first birth at ages 10 to 14 and 15 to 19 years respectively. Residing in urban areas in Nigeria (OR=0.37; CI=0.28 to 0.50) and Congo DR (OR=0.66; CI=0.45 to 0.98) reduces the risk of PC. The odd of PC reduces as the level of wealth quintile increases in Nigeria, Rwanda and Namibia. The identified determinants of PC included never use of contraceptive, Christianity, Islam and early sexual initiation. The study thus revealed premarital childbearing is still a problem in sub-Saharan Africa and the hardest hit country is Namibia and women with no formal education. Strategies aimed at reducing PC among UFY in this region should include improvement in female education.

Key words: Premarital childbearing, unmarried female youths, premarital sex.

INTRODUCTION

Premarital births are births occurring to women before their first marriage and it is one of the fundamental indicators of monitoring fertility trends in different countries (Bachu, 1999). Marriage postponement among women in pursuit of academic and career advancement, cohabitation, poor education along with poverty have

exposed women to higher risks of premarital births (Shell-Duncan and Wimmer, 1999). Consequently, the first five theme of the Millennium Development Goals to eradicate extreme poverty and hunger, achieve universal primary education, promote gender equality and empower women, reduce child mortality rates and improving

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maternal health (World Bank, 2002) would remain unrealizable if premarital childbearing (PC) remains a problem. The issue of premarital births has gained interest of importance concerns in the literature (Arnstein, 2003).

Right away from the ancient times, African diverse cultures have strong aversion for PC and Africans understood it to be illegitimate behaviour. In some parts of Africa, local deprecating names are given to children born out-of-wedlock, and their mothers are stigmatized in the community in order to discourage such behaviour. In Malawi for example, these children are referred to as “children without fathers”, “child of the bush”. Yoruba people in Nigeria referred to such children as “*omoale*” meaning bastard. However, recently, having babies and being unmarried has undergone changing levels of acceptance by various social institutions such as families, schools, public and private institutions (Scott and Eric, 2000). Premarital childbearing can occur at any age but the societal attitudes to the victims become less condemnatory after about age 25, as women are judged to have waited long enough for marriage (Pitso and Gordon, 2003).

In recent times, a number of sub-Saharan African countries have experienced a marked rise in births among unmarried female youths. One hypothesis used to explain the increasing frequency of PC in sub-Africa is a breakdown of traditional social controls by the extended family over the sexual behaviour of adolescents (Cicely and Eleanor, 2006; Eaton et al., 1998). A competing hypothesis suggests that unmarried women use sexual relations to achieve specific goals such as marriage, financial gain, job opportunities and other supports from their male partners (Shell-Duncan and Wimmer, 1999).

The social and health implications of PC have more negative influence on female youths than their male counterparts (Tiisetso, 2002). Female youths who find themselves in this situation are often neglected and uncared for, because the society and family believe that they are the sole cause of their adversity (Zwang and Garenne, 2002). Such young women are likely to be anaemic, malnourished during pregnancy and suffer from severe complications during delivery, which result in higher morbidity and mortality for both themselves and their children (Ikamari, 2005). In addition, their socio-economic development in the areas of educational attainment and accessibility to job opportunities may be curtailed (Abma et al., 2004; Chevalier and Viitanen, 2001). Having a child out of wed-lock can have considerable effects on his/her upkeep, health and survival, particularly if the custody of the child remains with a parent who is not economically viable (Abma et al., 2004; Arnstein, 2003).

Premarital childbearing among youths is known to be one of the public health problems of great concern particularly in developing countries where poverty and access to quality health care are part of the challenges

which pose threat to survival chances of individuals (Ana et al., 2013). It will continue to emerge as an issue of great importance and more focus of heated debates among the general public, policy makers and researchers (Shelly and Robert, 1995; Garenne et al., 2000). Sub-Saharan Africa is one of the regions where PC among female youths is highest globally (World Population Monitoring, 2000; South African Government Publication, 1998). The high prevalence in this region is likely to have adverse consequences on young mothers, their children and long term impact on the economic development of the region. For instance, analysis of data from the 1993 Kenya and 1992 Namibia Demographic and Health Surveys show that PC is an important risk factor for the under-utilization of maternity care (Gage, 1998). In both countries, women with premarital births were significantly less likely than those with marital births to seek prenatal care in the first trimester (Gage, 1998).

The demographic, socio-economic and cultural consequences of PC have made many scholars to focus more on its determinants and socio-economic correlates among youths in different countries (Mturi and Moerane, 2001; Garenne et al., 2000). However, such studies have not been adequately addressed in sub-Saharan Africa. Therefore, we designed this study with the view to exploring the patterns and differentials in the levels of PC. The study also identifies the factors that might account for high cases of PC in the region. The countries included in this study represent a variety of regional blocks in sub-Saharan African. This includes: Nigeria and Senegal in West Africa, Congo DR in Central Africa, Namibia in Southern Africa, and Rwanda and Malawi in East Africa. In each of the countries, the population is young and majority of households are located in rural areas. Levels of fertility are generally high, with the total fertility rate ranging from 3.3 in Namibia in 2006/7 to 6.3 in Congo DR in 2007 (Population Reference Bureau – PRB, 2012).

MATERIALS AND METHODS

Data collection

The study focused on unmarried young women (aged 15 to 24 years) from the most recent rounds of Demographic and Health Surveys (DHS) in 6 selected countries from the four regional blocks in sub-Saharan African. The selected DHS are: Nigeria, 2008; Senegal, 2010; Rwanda, 2010; Malawi, 2010; Congo DR, 2007 and Namibia, 2006/2007. The selection was based on data availability at meeting the goals of the study. We extracted the data from measure DHS database and as such, the methodologies involved in the collection process are available to interested readers in the DHS reports of the selected countries obtainable from measure DHS website (<http://www.measuredhs.com/>).

Data analysis

The dependent variable was “PC” which was created using the variable children ever born (CEB). The variable CEB was re-coded

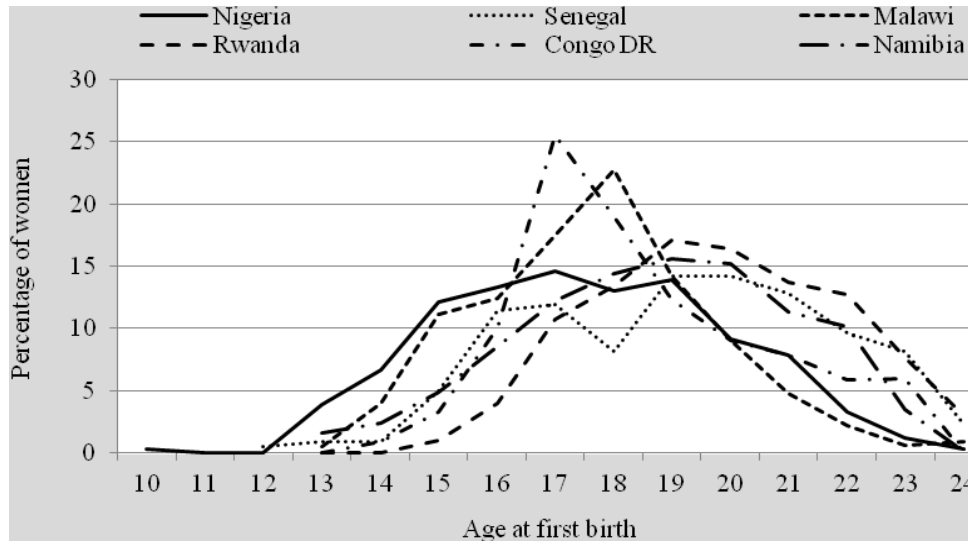


Figure 1. Line graph of patterns of age at first birth.

as 0 if no child was previously born by the respondent and 1 if otherwise. Code 1 was used as an indicator of PC. Data analysis was carried out using descriptive, Chi-square statistic and logistic regression model. At bivariate, chi-square was used to examine the association between the PC and independent variables such as; age, education, religion, residence, contraceptive use, age at first sexual intercourse and wealth quintile in all the selected countries. Independent variables found to be significant at bivariate were entered into logistic regression model in order to identify those that are causal of pre-marital childbearing.

The logistic regression is of the form

$$\log\left\{\frac{\gamma}{1-\gamma}\right\} = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_3 + \dots + \beta_nx_n$$

Where; $\gamma = 1$ represents the proportion of female youths that has given birth to at least a child and $\gamma = 0$ if otherwise. The independent variables are x_i ($i=1$ to n) and β_i ($i=1$ to n) are regression parameters to be estimated. The odds ratio (e^β) and 95% confidence interval of e^β were thereafter determined.

RESULTS

Univariate: Socio-demographic characteristics

The data as shown in Table 1 depict that in all the analysed countries, majority of the Unmarried Female Youths (UFY) were aged 15 to 19 years and we found highest percentage of such young women in Malawi (85.1%). Higher number of UFY was observed in rural areas of Nigeria (53.8%), Malawi (76.4%), Rwanda (80.9%) and Namibia (54.8%) whereas in Senegal and Congo DR, higher percentage of UFY was found in urban areas, 53.7 and 58.4% respectively. Majority of the young women consisted those with secondary education in 4 out of the 6 selected countries (Nigeria, Senegal, Congo

DR and Namibia) while those with primary education were found mostly in Malawi and Rwanda.

The data also show that percentage of UFY increases with increasing wealth quintile and this pattern is similar among all the countries analysed except Senegal, which was slightly at variance with the pattern. In three of the four countries with information on contraceptive use, majority of the UFY had never used any contraceptive method. For instance, in Nigeria, 78.1% of UFY had never used any contraceptive method as against 48.7% in Namibia. Classification of the respondents by religious affiliations depicts that in all the countries, majority of the UFY are Christians. Also, above half of the youths had never had sexual intercourse in five of the analysed countries, these are; Nigeria, Senegal, Malawi, Rwanda and Congo DR. Very few UFY had their first sexual initiation at ages 20 to 24 years.

As shown in Figure 1, the age at first birth is approximately normally distributed in all the six analysed countries and the mean value varies across the countries; Nigeria (18.46±2.43 years), Senegal (19.13±2.57 years), Malawi (17.69±2.03 years), Rwanda (19.79±2.11 years), Congo DR (18.49±2.13 years) and Namibia (19.17±2.33 years). It is evident in the figure that clear variation exists in age at first birth between the countries. In addition, the majority of the young women had their first birth at age 15 to 19 years. Early childbearing was mostly common in Malawi with 4.5 and 78.0% of young women having their first birth at ages 10 to 14 and 15 to 19 years. In Rwanda, none of the young unmarried women had their first birth at age 10 to 14 years (Figure 2).

Bivariate analysis results

Table 2 shows the percentage distribution of PC by

Table 1. Frequency distribution of the unmarried females aged 15 to 24 years in Nigeria, Senegal, Malawi, Rwanda, Congo DR and Namibia.

Background characteristics	Nigeria		Senegal		Malawi		Rwanda		Congo DR		Namibia	
	n	%	n	%	n	%	n	%	n	%	n	%
Total	6940	100.0	3582	100.0	4341	100.0	4476	100.0	2145	100.0	3530	100.0
Age												
15-19	4586	66.1	2572	71.8	3693	85.1	2863	64.0	1532	71.4	2122	60.1
20-24	2354	33.9	1010	28.2	648	14.9	1613	36.0	614	28.6	1408	39.9
Residence												
Urban	3205	46.2	1924	53.7	1024	23.6	854	19.1	1254	58.4	1594	45.2
Rural	3735	53.8	1658	46.3	3317	76.4	3622	80.9	892	41.6	1936	54.8
Education												
None	319	4.6	1043	29.1	84	1.9	170	3.8	229	10.7	57	1.6
Primary	803	11.6	812	22.7	2729	62.9	3067	68.5	701	32.7	651	18.4
Secondary	5208	75.1	1693	47.3	1404	32.3	1191	26.6	1126	52.5	2686	76.1
Higher	610	8.8	34	0.9	125	2.9	48	1.1	89	4.2	135	3.8
Wealth Quintile												
Poorest	520	7.5	470	13.1	675	15.5	670	15.0	279	13.0	585	16.6
Poorer	849	12.2	713	19.9	637	14.7	795	17.8	266	12.4	662	18.8
Middle	1412	20.3	993	27.7	736	17.0	867	19.4	363	16.9	649	18.4
Richer	1930	27.8	742	20.7	825	19.0	891	19.9	435	20.3	782	22.1
Richest	2228	32.1	664	18.5	1468	33.8	1253	28.0	802	37.4	852	24.1
Contraceptive use												
Never used	5420	78.1	NA	NA	3706	85.4	NA	NA	1498	69.8	1719	48.7
Folkloric	23	0.3	NA	NA	3	0.1	NA	NA	13	0.6	11	0.3
Traditional	166	2.4	NA	NA	19	0.4	NA	NA	305	14.2	23	0.6
Modern	1330	19.2	NA	NA	613	14.1	NA	NA	330	15.4	1778	50.4
Religion												
Christianity	5323	76.7	241	6.7	2095	48.3	3839	85.8	2100	97.9	9617	98.1
Islam	1554	22.4	3335	93.1	118	2.7	524	11.7	22	1.0	0.0	0.0
Traditional	27	0.4	5	0.1	309	7.1	57	1.3	4	0.2	0.0	0.0
Others	35	0.5	1	0.0	1348	31.1	56	1.3	19	0.9	187	1.9
AFSI												
None	4404	63.4	3137	87.6	3090	71.2	3699	82.6	1161	54.1	2673	27.3
8-14	352	5.1	95	2.7	343	7.9	165	3.7	246	11.4	608	6.2
15-19	1729	24.9	307	8.6	821	18.9	469	10.5	681	31.7	5023	51.2
20-24	455	6.6	38	1.1	87	2.0	143	3.2	50	2.4	1500	15.3

AFSI: Age at first sexual intercourse; NA: Not available during the survey.

socio-demographic characteristics among female youths in Nigeria, Senegal, Malawi, Rwanda, Congo DR and Namibia. The data show that PC among youths was mostly common in Namibia (25.5%) than any of the countries considered in the analysis, but the least prevalence of PC was found in Nigeria (4.8%). Across all the 6 countries, PC was higher among UFY in age group

20 to 24 years than those in the younger age group (15 to 19 years). PC was predominantly higher in rural areas than urban in Nigeria (6.3%), Senegal (6.2%), Congo DR (8.6%) and Namibia (27.7%) but the reverse is the case for Malawi and Rwanda.

The data further show that in 3 of the analysed countries, PC was more prominent among women with

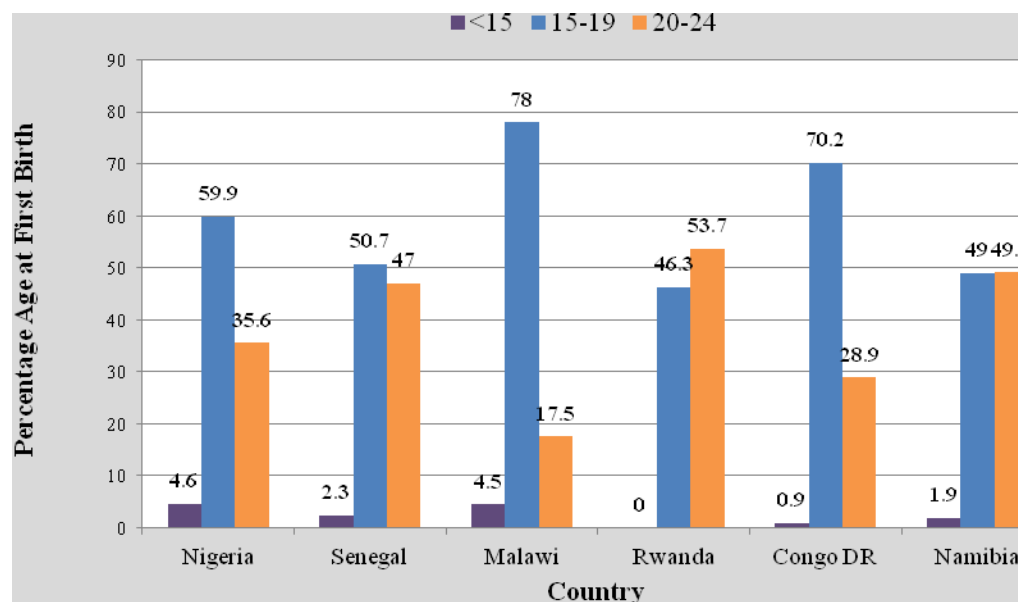


Figure 2. Bar charts of patterns of age at first birth.

Table 2. Premarital childbearing and socio-demographic characteristics among female youths in Nigeria, Senegal, Malawi, Rwanda, Congo DR and Namibia.

Background variables	Percentage of Premarital Births					
	Nigeria	Senegal	Malawi	Rwanda	Congo DR	Namibia
Total	4.8(330)	6.1(219)	6.6(286)	6.7(299)	7.0(150)	25.5(900)
Age	p=0.000	p=0.000	p=0.000	p=0.000	p=0.000	p=0.000
15-19	2.8(130)	3.0(76)	4.0(149)	2.5(73)	3.7(57)	9.8(207)
20-24	8.5(200)	14.2(143)	21.1(137)	14.0(226)	15.2(93)	49.2(693)
Residence	p=0.000	p=0.930	p=0.000	p=0.048	p=0.012	p=0.001
Urban	2.9(93)	6.1(117)	7.1(73)	8.2(70)	5.8(73)	22.8(363)
Rural	6.3(237)	6.2(102)	6.4(212)	6.3(229)	8.6(77)	27.7(537)
Education	p=0.000	p=0.001	p=0.000	p=0.000	P=0.548	p=0.000
None	1.6(5)	5.3(55)	4.8(4)	16.5(28)	7.9(18)	54.4(31)
Primary	9.7(78)	8.9(72)	5.4(148)	6.9(211)	6.3(44)	32.4(211)
Secondary	4.5(235)	5.4(92)	9.3(130)	4.9(58)	7.5(84)	23.9(643)
Higher	2.0(12)	0.0(0)	3.2(4)	4.2(2)	4.4(4)	10.4(14)
Wealth Quintile	p=0.000	p=0.000	p=0.162	p=0.071	p=0.278	p=0.000
Poorest	10.2(53)	8.3(39)	5.6(38)	8.8(59)	10.0(28)	30.6(179)
Poorer	7.2(61)	8.0(57)	5.3(34)	7.3(58)	7.1(19)	25.4(168)
Middle	5.9(83)	6.9(69)	5.7(42)	5.9(51)	5.8(21)	29.7(193)
Richer	4.4(85)	4.9(36)	7.9(65)	5.4(48)	7.1(31)	28.4(222)
Richest	2.2(49)	2.7(18)	7.2(105)	6.6(83)	6.5(52)	16.2(138)
Contraceptive use	p=0.000	NA	p=0.000	NA	p=0.000	p=0.000
Never used	3.2(176)	NA	3.7(136)	NA	3.5(53)	6.8(116)
Folkloric	17.4(4)	NA	33.3(1)	NA	0.0(0)	9.1(1)
Trad. meth	8.4(14)	NA	15.8(3)	NA	16.1(49)	18.2(4)

Table 2. Contd.

Modern method	10.3(137)	NA	23.7(145)	NA	14.2(47)	43.8(778)
Religion	p=0.000	p=0.000	p=0.001	p=0.070	p=0.563	p=0.175
Christianity	5.9(312)	15.8(38)	5.4(114)	6.5(249)	7.1(149)	25.5(884)
Islam	1.0(15)	5.4(180)	14.4(17)	7.1(37)	0.0(0)	0.0(0)
Traditional	11.1(3)	20.0(1)	5.2(16)	14.0(8)	0.0(0)	0.0(0)
Others	0.0(0)	0.0(0)	6.5(87)	0.0(0)	5.6(1)	47.1(17)
AFSI	p=0.000	p=0.0341	p=0.000	p=0.000	p=0.000	p=0.000
8-14	22.2(78)	48.4(46)	16.0(55)	12.7(21)	18.4(45)	51.3(96)
15-19	12.3(213)	49.8(153)	26.0(213)	45.6(214)	14.1(96)	43.7(702)
20-24	5.3(24)	44.7(17)	9.2(8)	40.6(58)	5.9(3)	29.9(59)

NPBC: Number of premarital birth cases; NA: Not available during the survey.

no formal education as found in Rwanda (16.5%), Congo DR (7.9%) and Namibia (54.4%). In Nigeria and Senegal, proportion of women who had experienced PC was mostly reported by those who had primary education; 9.7% and 8.9% respectively. According to wealth quintile, the proportion of UFY who had given birth to at least a child reduces with an increasing wealth quintile as observed in Nigeria, Senegal, Rwanda, Congo and Namibia. In all the four countries with available data on contraceptive use, the prevalence of PC was higher among ever users than never users. Also, comparison of PC between the two most popular religion (Christianity and Islam), PC was higher among Christians in Nigeria and Senegal than Muslims but a reverse pattern in Malawi and Rwanda.

Multivariate analysis results

As shown in Table 3, the data show that in Senegal, Malawi, Rwanda, Congo DR, Namibia women in age group 15 to 19 years were 0.252 (CI=0.158 to 0.402), 0.207 (CI=0.142 to 0.302), 0.299 (CI=0.205 to 0.437), 0.259 (CI=0.174 to 0.387) and 0.136 (CI=0.108 to 0.171) less likely to experience PC than those in age group 20 to 24 years respectively. Residing in urban areas in Nigeria (OR=0.373; CI=0.280 to 0.497) and Congo DR (OR=0.660; CI=0.447 to 0.975) reduces the risk of PC among the UFY. There was a variation in pattern of relationship between PC and levels of education in the countries. The data show that the risk of PC was higher among UFY with no formal and primary education than those with higher education. The odds of having premarital birth significantly reduces as the level of wealth quintile increases as observed in Nigeria, Rwanda and Namibia.

For contraceptive use, Nigeria is the only country where a significant relationship exists between contraceptive use and PC. In Nigeria UFY who had never used any contraceptive method were 1.283 (CI=0.977 to

1.685) times more likely to have had at least a child out of wedlock than those who had ever used contraceptive method. The odds of PC was also significantly lower among Muslims (OR=0.305; CI=0.173 to 0.538) in Nigeria than Christians, whereas Muslim UFY in Malawi were 3.771(CI=1.862 to 7.639) more likely to be at risk of PC than Christians.

In 4 out of the 6 countries, UFY who began sexual initiation at younger age were at higher risk of PC than those who started later. For instance, in Nigeria, UFY who were aged 8 to 14 and 15 to 19 years at the time they encountered first sexual intercourse were 5.767(3.345 to 9.944), 2.665(CI=1.674 to 4.241) more likely to have had at least a child than those who began in ages 20 to 24 years respectively. Similar pattern exists for Senegal, Congo DR and Namibia.

DISCUSSION

Globally, increasing prevalence of PC among young women has been widely reported (Perelli-Harris and Gerber, 2009; Meekers, 1993; Gage, 1998). While previous studies have suggested that unmarried African women sometimes use childbearing as a strategy to fast-track transition to marriage and other benefits, PC has a strong negative effect on an unmarried female youth's chances of first marriage (Kearney and Phillip, 2012; Calvès, 1999). Aside its substantial contribution to rapid population growth (Bongaarts, 1994), the victims and their children are often faced with numerous social and health challenges (Gage, 1998; Calvès, 1999; Jensen and Thornton, 2003).

Our study has revealed that aside from a few notable exceptions, there remains a very high case of PC in sub-Saharan Africa. It is evident that in all the studied countries particularly Malawi, most of the UFY clustered around ages 15 to 19 years and higher proportion are residents in rural areas of Nigeria, Malawi, Rwanda and Namibia. Also, the young women mostly had at least

Table 3. Multiple logistic regression of PC and socio-demographic characteristics.

Background variables	OR(95% CI)					
	Nigeria	Senegal	Malawi	Rwanda	Congo DR	Namibia
Age (years)						
15-19	0.845 (0.611-1.168)	0.252* (0.158-0.402)	0.207* (0.142-0.302)	0.299* (0.205-0.437)	0.259* (0.174-0.387)	0.136* (0.108-0.171)
20-24 (RC)	1	1	1	1	1	1
Residence						
Urban	0.373* (0.280-0.497)	NSAB	0.823 (0.558-1.215)	0.838 (0.526-1.335)	0.660*** (0.447-0.975)	0.789 (0.590-1.054)
Rural (RC)	1	NSAB	1	1	1	1
Education						
None	2.800**** (0.858-9.134)	1.000(R.C)	9.433*** (1.436-61.946)	21.033** (2.444-181.037)	NSAB	8.399* (3.209-21.984)
Primary	8.199* (4.117-16.329)	0.927 (0.518-1.657)	9.509* (3.117-29.008)	14.118*** (1.774-112.333)	NSAB	7.071* (3.620-13.813)
Secondary	2.769* (1.498-5.118)	0.425** (0.245-0.737)	6.204** (2.108-18.259)	9.786*** (1.226-78.123)	NSAB	3.410* (1.854-6.272)
Higher (RC)	1	1	1	1	NSAB	1
Wealth Quintile						
Poorest	3.522* (2.073-5.982)	0.586 (0.586-3.228)	NSAB	2.241** (1.287-3.903)	NSAB	1.991** (1.283-3.091)
Poorer	2.765* (1.693-4.516)	0.678 (0.678-3.382)	NSAB	2.197** (1.229-3.928)	NSAB	1.760 (1.153-2.685)
Middle	1.921** (1.237-2.983)	0.628 (0.628-3.014)	NSAB	1.341 (0.775-2.319)	NSAB	1.828** (1.267-2.637)
Richer	1.445**** (0.970-2.153)	0.534 (0.534-2.955)	NSAB	1.140 (0.668-1.944)	NSAB	1.455** (1.076-1.969)
Richest (RC)	1	1	NSAB	1	NSAB	1
Contraceptive use						
Never used	1.283**** (0.977-1.685)	NIA	1.023 (0.735-1.423)	NIA	1.268 (0.796-2.019)	0.860 (0.637-1.160)
Folkloric	1.526 (0.477-4.887)	NIA	0.000 (0.000)	NIA	0.377 (0.016-8.706)	0.633 (0.038-10.533)
Traditional	0.714 (0.384-1.327)	NIA	0.759 (0.115-4.996)	NIA	1.356 (0.845-2.177)	0.403 (0.112-1.444)
Modern (R.C)	1	NIA	1	NIA	1	1
Religion						
Christian (RC)	1	1	1	1	NSAB	NSAB
Islam	0.305* (0.173-0.538)	0.874 (0.502-1.522)	3.771* (1.862-7.639)	0.901 (0.553-1.470)	NSAB	NSAB
Traditional	1.790 (0.405-7.908)	1.076E5 (0.000)	0.983 (0.536-1.801)	3.365*** (1.118-10.133)	NSAB	NSAB
Others	0.000 (0.000)	200.768 (0.000)	1.393**** (0.986-1.968)	0.000 (0.000)	NSAB	NSAB
AFSI						
8-14	5.767* (3.345-9.944)	2.936*** (1.224-7.044)	4.326** (1.792-10.443)	0.359** (0.187-0.688)	10.132** (2.654-38.682)	5.395* (3.306-8.802)

Table 3. Contd.

15-19	2.665* (1.674-4.241)	2.032**** (0.974-4.238)	6.497* (2.895-14.581)	1.667*** (1.081-2.572)	5.691** (1.558-20.793)	3.007* (2.120-4.265)
20-24 (RC)	1	1	1	1	1	1
-2 LogL	1647.299	555.602	993.251	865.076	757.846	2279.864
Cox&Snell R ²	0.097	0.260	0.097	0.178	0.129	0.369
Nagelkerke R ²	0.184	0.709	0.151	0.242	0.332	0.549

*, **, ***, **** Significant at 0.1, 1.0, 5.0 and 10.0%, respectively; NSAB: Not significant at bivariate; NIA: Not included in the analysis; CI: Confidence Interval; RC: Reference category; AFSI: Age at first sexual intercourse.

secondary education in Nigeria, Senegal, Congo DR and Namibia while those with primary education constituted the majority in Malawi and Rwanda. The proportion of the UFY increases as the level of wealth quintile increases in all the countries but Senegal a country from the West Africa exhibits a slight discrepancy from this pattern. Too often, in Senegal as in the rest of West and Central Africa, poverty is a massive challenge and it may result in taking or keeping female children out of school. For instance, of the 10 countries worldwide with the lowest ratio of girls to boys in school, eight are located in West and Central Africa. In Senegal, almost two-thirds of women aged 15 years and above are illiterate, and 16% finish elementary school and proceed to secondary school (UNICEF, 2005).

Information on contraceptive use was available for four countries. The countries are Nigeria, Malawi, Namibia and Congo DR; the majority of UFY were 'never used any contraceptive method' except in Namibia. We expect this finding since the mainstream of the UFY studied had never had sexual intercourse; it was only in Namibia where 72.8% of the young women ever had sexual intercourse. The age at first sexual intercourse has been found in previous studies as an important factor influencing contraceptive use (Martinez et al., 2011; Abma and Dawson, 2005). It is understandable that a woman who has not

begun sexual initiation will not use contraceptive either to prevent fertility or sexually transmitted diseases.

Mother's age at first birth is one of the important determinants of fertility and one of the key determinants of maternal and child's health. If a woman starts child bearing at a very young age, she is more likely to bear many children at the end of her reproductive age, especially in a country where there is a low prevalence of contraceptive use and relatively short birth intervals (Adebowale et al., 2011). The pattern of mean age at first birth was similar across the countries but shows a slight disparity ranging from 17.7 in Malawi through 19.8 years in Rwanda. This is an indication of early PC in Malawi than other countries studied and the finding is in agreement with the result from a previous study conducted in Malawi (National Statistical Office - UNICEF, 2008). In the 6 countries, higher prevalence of PC was observed among UFY in age 20 to 24 years than the younger women. A longer period of exposure to sexual intercourse is an important factor to reckon with in this regard.

Our study further revealed that, the prevalence of PC (PC) was highest in Namibia (Southern Africa) and least in Nigeria (West Africa). This observation is in agreement with the finding by Tawiah (2002) when he observed that adolescent fertility is highest in Zambia and lowest in Ghana,

two countries from west and southern Africa respectively. Highest PC in Namibia could be linked with early sexual initiation experienced by majority of young women in the country (Gage, 1998; Maletsky, 2005). Also, a considerable number of Nigerians are Muslims, a religion which has been found in literature as pro-early marriage. Early marriage reduces the risk of premarital births and might be a contextual link to least PC experienced by UFY in Nigeria.

Higher prevalent of PC was observed in rural than urban areas of Nigeria, Senegal, Congo DR and Namibia, but as for the selected countries from East Africa (Malawi and Rwanda) the reverse pattern was recorded. The finding for the patterns observed for Malawi and Rwanda is in agreement with studies conducted in Poland and Nigeria. For example, in the Poland study, it was revealed that since the probability that a premarital conception leads to a "shotgun marriages" has remained higher in villages than in the towns, out-of wedlock births were spreading at higher pace in urban than in rural areas (Anna, 2011; Oyefara, 2012). In Rwanda, Congo DR and Namibia, PC was more prominent among women with no formal education. However, in Nigeria and Senegal, proportion of women who had experienced PC was highest among UFY who had primary education.

With respect to wealth quintile, the proportion

of UFY who had experienced PC increases with reduction in wealth quintile as observed in Nigeria, Senegal, Rwanda, Congo and Namibia. In these countries being poor is associated with increased risk of PC. This is in agreement with findings from other various studies that show that economic factors have a significant role in young women's sexuality and childbearing (Katherine et al., 2009; Kathryn and Kefalas, 2005). For instance, Katherine and colleagues in their study found that the association between age at first birth and wealth quintile was negative (Katherine et al., 2009). It is often said that young girls particularly those from the poor family enter into sexual relationship with older and wealthy men to meet their school related expenses in addition to their daily needs. Whereas, others engage in premarital sex with men of important personality in order to establish a long term relationship for future assistance either for self or members of their families.

In all the four countries with available data on contraceptive use, we found that the prevalence of PC was higher among ever users than never users. This finding is striking in the sense that one would have expected a reverse pattern since the use of contraceptive tends to protect fertility and indirectly reduces the risks of premarital births (Gage, 1998; Martinez et al., 2011). In a China study for instance, contrary to our finding, it was found where it was concluded that only a small proportion of those who were unmarried were using contraception, so induced abortion was often the outcome of unprotected premarital sex (Zhenzhen et al., 2001). However, a possible justification for our finding is that young women who have earlier experienced PC might be cautious of having unprotected sex, thus increase in the prevalence of contraceptive use among such women is likely.

Religion has the potential to influence the acceptance and use of contraception by young women in very distinct ways. Within religions, different sects may interpret religious teachings on contraception in varying ways, and individual women and their partners may choose to ignore religious teachings (Jones and Dreweke, 2011; Amirrtha and Robert, 2008). Finally, our study revealed that the likelihood of PC was higher among Christians than their Muslim counterparts particularly in countries in West Africa (Nigeria and Senegal) while in East African countries (Malawi and Rwanda) the reverse pattern was observed. Nigeria and Senegal have large Muslim population and among the religion, it is evidenced that early marriage was more common among Muslims than Christians (Adebowale et al., 2012). Early marriage is known to be a strong protective factor against premarital sex and PC.

Multivariate analyses identified age, education, age at first sexual intercourse and wealth quintile as the most important explanatory variables of PC in virtually all the countries examined. In Sub-Saharan Africa, literature is consistent with reduction in the level of age at first sexual

intercourse (Nigeria Demographic and Health Survey, 2008; Kenya Demographic and Health Survey, 2010; Malawi Demographic and Health Survey, 2004; Garenne and Zwang, 2006). The implication is that episode of high level of PC might surface in the region in the future except if fertility control measures are constantly utilized. The study also shows that the educational level of the respondent is one of the major factors influencing PC. This indicates that raising the level of education is one effective strategy of discouraging PC in sub-Saharan Africa.

Limitations of the study

The study was based on data obtained through cross-sectional examination of the respondents and as such, the data are susceptible to response bias, as some of the unmarried female youths who had given birth might not disclose their true status at the time of the survey. This tends to reduce the number of cases of premarital pregnancy. In addition, age misreporting which is peculiar to African survey data is also likely to be a problem. Moreover, differences exist in the number of variables used in the analysis for the countries. This is because of absence of these variables in some of the countries analysed. For instance, region was not included in the analysis because it is not a variable that has common nomenclature among all the countries and its classification is different between countries.

Conclusion

This study shows that PC among UFY is still a common problem and the level varies greatly within countries in sub-Saharan Africa. The hardest hit country is Namibia and those with no formal education. Government in this region should begin campaign on the adverse effect of PC on female youths at early years of life. This will reduce the prevalence of premarital births and its associated socioeconomic and health effects on UFY.

Conflict of Interests

The author(s) have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank the ICF International in the United States of America, especially the DHS program, for releasing the data for this study.

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Full Length Research Paper

Medical waste management practices among selected health-care facilities in Nigeria: A case study

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Received 5 March, 2014; Accepted 29 April, 2014

Inappropriate medical waste (MW) management practices have become one of the major concerns in developing countries. The objectives of this study are to appraise the procedures and techniques available in collection and segregation of MW, treatment and recycling processes, disposal practices and compliances with rules and regulations in the Health-care Facilities (HCFs) in Ota, South West Nigeria. The HCFs visited includes general hospital, private hospitals, clinics, and primary health-care centers. The survey involved the use of structured questionnaires, in-depth interviews and on-site observations. Statistical Package for Social Sciences (SPSS) software application was employed for analysis. Responses were coded using a linkert scaling procedure. Hypotheses were tested using Bivariate regression technique involving inferential statistics. In addition, the study utilized chi-square non-parametric test for normal distributional effect of the variables. Results showed that MW management practices in most facilities are not totally in line with prescribed standards as expected. It is recommended that a sustained cooperation should be developed among all key actors (government, HCF's responsible and waste managers) so as to implement a safe and reliable medical waste management strategy. This should not only be limited to legislation and policy formulation but also in its monitoring and enforcement.

Key words: Medical waste management, health-care facilities, statistical analysis, health risk, sustainability practice.

INTRODUCTION

Generation of waste is indispensable with respect to Health-care Facilities (HCFs) activities, but knowledge of its hazards and good disposable practices has been very poor. Medical waste has continued to generate increasing public interest due to the health problems associated with exposure of human beings to potentially hazardous wastes arising from health-care facilities (Tudor et al., 2005; Da Silva et al., 2005; Oke, 2008;

Coker et al., 2009; PATH, 2009; Adegbite et al., 2010). Medical wastes are from hospitals, primary health-care centers (PHCs), dispensaries, dialysis centers, first-aid posts and sick bays, medical and biomedical laboratories, biotechnology laboratories, medical research centers, mortuary and autopsy centers, blood banks and blood collecting centers, nursing homes for elderly, maternity homes, pharmaceutical, chemical and chemist stores

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(WHO, 1994, 1995; Tudor et al., 2005; Mokuolu, 2009). Studies have highlighted that ineffective management of infectious hospital waste in developing countries can compromise the quality of patient care and create significant occupational public and environmental health risks (Cole, 2000; Coker et al., 2009).

Although, treatment and disposal of health-care waste aims at reducing risks, indirect health risks may occur through the release of toxic pollutants into the environment during treatment or disposal. Improper handling of medical waste can create harmful effects and reduce the overall benefits of health-care. Studies conducted in developing countries regarding Medical waste management (MWM) has described it as being poor and that the general awareness on related issues is lacking among generators and handlers (Manyele et al., 2003). Despite the fact that health-care waste is labeled as hazardous because of the serious direct threat it poses to human health (WHO, 1999), the situation of poor MWM is still common in developing countries like South Africa, Nigeria, Swaziland, Mozambique, Kenya and Tanzania (Manyele et al., 2003; Manyele, 2004). An assessment conducted in 22 developing countries in 2002 showed that 18 to 64% of HCFs do not use proper waste disposal methods (WHO, 2002). Generally, lack of awareness about health hazards, poor management practice, insufficient financial and human resources and poor control of waste disposal are the most common problems connected with MWM in developing countries like Nigeria.

No doubt some studies have been conducted on waste generation, segregation and disposal, but little attention has been given to awareness of potential risks associated with medical waste and the need of personnel protection in rural and semi-urban settings. Presently, a gap exists in knowledge and practice among health personnel which requires being bridged not only for the study area but also in the entire nation. Manyele et al. (2003) expressed that developed nations recognized poverty as a basic factor that inhibited the success of African efforts in the area of environmentally sound management of hazardous waste. In Nigeria, medical waste falls under the category of infectious waste according to Federal Environmental Protection Agency (FEPA) now National Environmental Standards and Regulations Enforcement Agency (NESREA) (FEPA, 1991). This class of waste requires a particular type of management rather than being dumped with the rest of other waste. Speculations from various bodies have pointed out that in Nigeria; medical waste disposal has received no attention in contrary to what it deserves.

Health hazards due to improper MWM affect not only HCF's occupants but also spread into the vicinity.

Medical wastes are simply mixed with municipal waste in collection bins at roadsides and disposed off while some are simply buried without any appropriate measure. Lakshmi (2003) revealed that waste generated by

government hospitals is still largely being dumped in the open, waiting to be collected with general waste. Similar practice is seen where borrow-pits (pits where sand are collected during construction of express highways) are common dumpsites of general wastes including health-care wastes without being treated or having any concern for the safety of the masses. The following are environmental effects of improper waste management: Groundwater contaminations due to the leachate generated by the waste dump, surface water contamination by the run-off from the waste dump, generation of inflammable gases (e.g. methane) inside the waste dump, bad odor, pests, rodents and wind-blown litter in and around the waste dumps, acidity to the encircling soil and greenhouse gases emission. All these call for attention and standardization if good health is to be achieved and maintained at all times (IPHI, 2005).

Thus, objectives of this research are to: (a) determine the quantity of medical waste generated in kg/day; (b) examine methods of waste disposal; (c) ascertain if there is any form of training and regulations on the management of medical waste as well as level of awareness of medical waste management among health workers with a proposition of efficient methods of waste management in some selected Health-care Facilities (HCFs) in Ota, South West Nigeria.

METHODOLOGY

Study area

This study focuses on Ota metropolis, a town in the Ado-Odo local government of Ogun State, Nigeria. It has an estimated population of 526,565 residents living in and around it (NPC, 2009; Olukanni and Akinyinka, 2012). It covers an area of 885 square kilometers with an average density of 372 persons per square kilometer and lies between latitude 6° 58' N and longitude 6° 42' E. The Ado-Odo/Ota Local Government Area is one of the 20 Local Government Areas (LGAs) of Ogun State, Nigeria. Ado-Odo/Ota borders on metropolitan Lagos. The LGA is the second largest in Ogun State with Ota being its headquarter and having about four hundred and fifty (450) towns, villages and settlements. Towns and cities include Ado-Odo, Agbara, Igbesa, Iju-Ota, Itele, Koko-Ebiye, Ilewo-Alaga, Owode and Sango Ota, among others. The LGA has one secondary, 25 primary health-care facilities and 156 private health-care facilities. There was no data on the available number of laboratories and private diagnostic centers.

Sample and sampling technique

The study is directed on determining the understanding of health care workers on MWM and also assesses the current waste management practice of the HCFs. These facilities include general, and specialist hospitals, clinics, and health-care centers located in the North, South, East and West part of Ota. The criteria for selecting the HCFs were based on their prominence in the society and the willingness of the heads of each facility to provide information. Consents were taken from the heads and structured questionnaires on related issues were administered to the health-care workers.

The study employed parametric and non-parametric analytical

Table 1. Daily average waste generation and characterization.

Medical Waste (MW) component	Generated waste in each HCFs category (kg/day)			
	Tertiary	Secondary	Primary	Private/diagnostic
Plastics, nylon, paper	-	30.2	8.51	12.53
Sharps and needles	-	11.4	4.83	7.1
Swabs and absorbents	-	12.7	2.04	3.01
Used beddings, IV drips and pharmaceutical products	-	9.4	2.17	3.2
Infectious waste	-	3.3	0.56	0.8
Daily total generation (kg/d)	-	67	18.11	26.64
Average generation rate (kg/day)	-	0.45	0.31	0.39

technique in its method of data analysis. The survey involved the use of structured questionnaires administered to health-care workers, in-depth interviews and on-site observations which lasted for five months, January to May, 2013. The main items of the questionnaire were focused on medical waste segregation, collection, treatment, recycling process, waste disposal and waste management practices. The study also captures health workers understanding on the current MWM. The research instrument was divided into two parts. First part dealt with personal information of the respondent and the type of health-care facility that is currently being considered. In second part, respondents stated their experiences on the waste management practice in their various health-care facilities. Respondents were Doctors, Nurses, Pharmacists, Attendants and other medical experts. Names of health-care facilities assessed are not mentioned in this report for the purpose of confidentiality. However, consents were taken from each HCF's administrator before each survey was carried out.

Data analysis

Qualitative and quantitative data collected through questionnaire and observation were compiled and analyzed by using percentages and proportions as well as Statistical Package for Social Sciences (SPSS). Findings were then combined and presented as a whole assessment. Responses were coded using a linkert scaling procedure. Procedure combines descriptive analysis and bivariate regression estimation in arriving at the results obtained. The asymmetric distribution of the responses and the asymptotic significance of the hypotheses were verified for statistical significance and distributional effect using chi-square normal distribution test. The variables of analysis were first subjected to descriptive analysis involving frequency distribution and percentages.

The regression estimates were utilized to determine nature and direction of the relationship among the dependent and independent variables. Three hypotheses were made prior to conduct the study. The first one was that majority of the HCFs in Ota lack proper arrangement for handling and treatment of medical waste. The second was that, there is inadequate awareness of waste recycling process among medical workers in Ota and the third being that, there exist low adoption of MWM practices in most of the local health-care facilities in the study area.

RESULTS AND DISCUSSION

Classification of health-care facilities

HCFs are generally categorized based on their size,

function and type of services rendered. They are usually categorized into 4 classes: Tertiary, Secondary and Primary health care facilities—and Private/Diagnostic service laboratories. Tertiary health-care facilities are categorized based on the fact that they have modern equipments and a large number of specialists trained in handling a variety of health problems and, as a consequence, they serve as a referral hospital to many other hospitals in Nigeria. Large hospitals and clinics with capacity to handle simple to fairly complicated health problems are categorized as Secondary. Primary are relatively small in scope of healthcare delivery and usually treat only out-patients with simple ailments (Coker et al., 1999). The Private/Diagnostic service laboratories are owned by individuals to render essential health-care services and treatment to people in the community. Each other category of HCFs was visited in the course of this study except for Tertiary HCF that is not available in the study area.

Descriptive analysis

Table 1 shows the nature and average daily amount of medical waste (MW) generated for all HCFs measured. The Secondary HCF has a total generation rate of 67 kg/day. 45% of total solid medical waste material is comprised of plastics, Polyvinyl Chloride (PVC), paper, gauze pads, garments, and cellulose. Other main solid medical wastes were sharps and needles (17%), swabs and absorbents (19%), used beddings, drips and pharmaceutical products (14%). Overall, infectious wastes constituted only (5%) of total waste measured. A similar study conducted by Coker et al. (2009) in Ibadan, revealed similar values of infectious waste. The peak average rate of waste generation/facility was from secondary HCFs whose value of 67 kg/day was almost quadruple that of the primary HCFs 18.1 kg/day rate.

As shown in Table 1, Secondary HCFs have the highest average generation rate of 0.45 kg/day, followed by the private/diagnostic centers which have an average generation rate of 0.39 kg/day. The possible underlying reason for the substantial amount of medical waste

Table 2. Demographic information of Respondents-I.

Sex of respondent	Percent	Valid percent	Cumulative percent
Male	18.8	19.7	19.7
Female	76.6	80.3	100.0
Total	95.3	100.0	
Age of respondent			
19-24 years	7.8	8.1	8.1
25-30 years	21.9	22.6	30.6
31-40 years	40.6	41.9	72.6
40 years and above	26.6	27.4	100.0
Total	96.9	100.0	
Years actively engaged in the medical profession (years)			
Less than 5 years	26.6	28.3	28.3
5-10 years	28.1	30.0	58.3
11-15 years	14.1	15.0	73.3
16-20 years	7.8	8.3	81.7
20 years and above	17.2	18.3	100.0
Total	93.8	100.0	

generation in private hospitals is fundamentally linked with government expenditure reductions on health-related programs which have led to understaffing and other things in the primary HCFs. This was also supported by reports from the interviews. In the wards visited, 23% claimed that waste generated is collected 3 times daily, 13% twice, 63% at least once a day while in remaining 2%, the waste is collected from the bins as necessitated. Overall, the frequency of collection of waste from all the HCFs is in line with the WHO standard (WHO, 2002) which states that waste must not be stored for more than 24 h.

Pre-treatment and segregation of waste

In the entire survey, none of waste handlers pre-treat their medical waste prior to disposal. Lack of education or sheer ignorance of some waste handlers was exhibited because they see no need for pre-treatment. Some felt handicapped by the costs of setting up pre-treatment facilities. In the course of the study, questions were asked as regards to the segregation techniques being practiced in the HCFs. None of the HCFs currently practice any segregation techniques. All waste generated in every facility is not separated. The effect of this is an unsustainable waste management practice. Waste sorting and segregation practice has been known to aid substantial reductions in what would finally end up in the waste stream (Olukanni and Akinyinka, 2012).

Demographic information of respondents

Table 2 shows the percentage of total respondents which

indicate that majority of health care personnel were mostly females. The percentage distribution of the medical workers by age revealed that 41.9% of the sample study was between 31 to 40 years old, of which 30% carrying the highest percentage have been working in the medical area for 5 to 10 years.

The descriptive analysis of Table 3 gives an understanding that majority (68.8%) of health-care workers have been in the current employment for less than 5 years. Nurses are the preponderant profession (59.4%), followed by doctors (23.4%). Respondents were categorized according to the type of HCF where they are located, showing that the majority (60.9%) was from PHCs.

Figure 1 shows the rates at which health care workers go for training. Pharmacists and dieticians seldom go for training. On the other hand, doctors go for conference and workshops. One connecting link to doctors attending training is the fact that, points are awarded to doctors which accumulates towards their practicing license registration renewal. In this wise, every medical officer attend as many trainings and conferences as possible to meet up with the essential points.

Bivariate analysis

Table 4 shows the result of the bivariate analysis. Model I shows that there is a significant relationship between type of HCF and staff awareness regarding material recycling and waste management. It further revealed that HCFs with good waste management system would be willing to create more awareness concerning waste disposal and recycling while others with poor waste recycling could be

Table 3. Demographic information of Respondents-II.

Years of experience in current hospital			
	Percent	Valid percent	Cumulative percent
Less than 5 years	68.8	71	71
5-10 years	21.9	22.6	93.5
11-15 years	1.6	1.6	95.2
16-20 years	1.6	1.6	96.8
20 years and above	3.1	3.2	100
Total	96.9	100	
Description of job in the hospital			
Doctor	23.4	23.4	23.4
Nurse	59.4	59.4	82.8
Pharmacist	1.6	1.6	84.4
Others	15.6	15.6	100
Total	100	100	
Type of hospital respondents			
Specialist	1.6	1.6	1.6
General	34.4	35.5	37.1
Clinic/Health centre	60.9	62.9	100
Total	96.9	100	

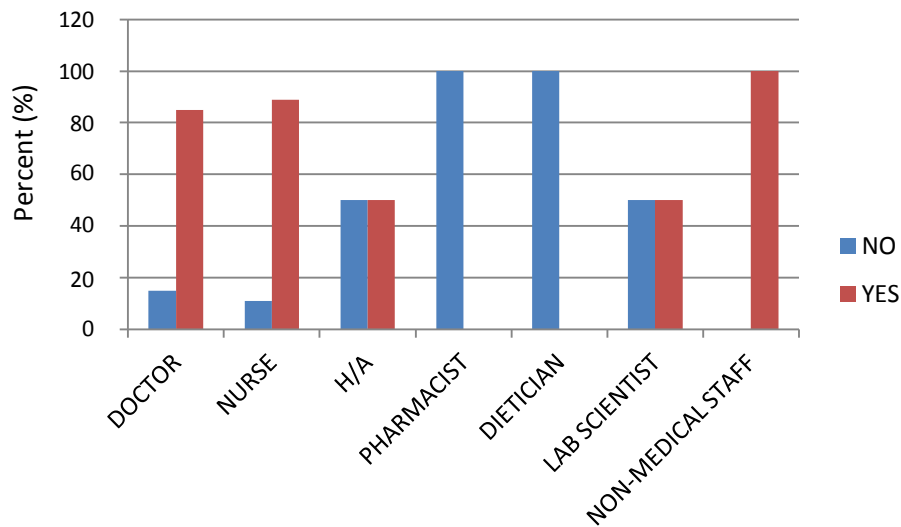


Figure 1. Distribution of training rates. H/A represents Health Attendants. The cleaners are grouped under non-medical staff.

silent about creating such awareness among their member(s) and staff. Model I also shows the relationship between types of HCFs and method adopted in providing instructive posters of waste segregation and management practice.

As depicted in the result of the surveyed HCFs, any HCF that adopts a conventional waste recycling approach would be willing to create awareness through the use of instructive posters and give directions on waste segregation, central collection point and disposal

locations. This would be made available for all concerned personnel for maximum compliance and strict adherence; hence this helps to boost the image of the HCF among others as one of best practitioners in hygiene and waste management. The result also validates the fact that HCFs with low or poor waste management practice do not have instructive posters on waste segregation around their facility. In Model I, the relationship between type of HCF and frequency of medical waste collection from the wards shows a significant inverse relationship. The empirical

Table 4. Bivariate results.

Model I: Type of HCF respondents	F-value	Beta	t-value	Sig.
(Constant)			-0.477	0.635
Are you aware of any material being recycled by the HCF?	11.900	0.435	3.450	0.001
(Constant)			2.642	0.011
Are there Instructive posters on waste segregation around the HCF?	22.982	0.529	4.794	0.000
(Constant)			14.135	0.000
What is the frequency of collection of medical waste from the wards (times/day)	7.113	-0.344	-2.667	0.010
Model II: Is there any special budget in the HCF for waste management?				
(Constant)			0.644	0.523
Are you aware of any materials being recycled by the HCF?	9.444	0.409	3.073	0.004
Model III: Are there instructive posters on waste segregation around the hospital?				
(Constant)			13.947	0.000
How long have you been actively engaged in the medical Service?	3.574	-0.243	-1.890	0.064
(Constant)			3.616	0.001
Is there any waste management committee in the HCF?	17.038	0.467	4.128	0.000
Model IV: Is there a manual or document on management of Health-care waste?				
(Constant)			14.113	0.000
Who is responsible for collecting, handling, storage and disposal of the medical wastes from the wards in the HCF?	8.682	-0.468	-2.946	0.006
(Constant)			25.503	0.000
How long have you been actively engaged in the medical service?	6.752	-0.429	-2.598	0.014
Model V: Is there any waste management committee in the HCF?				
(Constant)			4.225	0.000
Is there is any special budget your facility for waste management?	45.322	0.672	6.732	0.000
(Constant)			17.598	0.000
What is the frequency of collection of medical waste from the wards (times/day)?	9.302	-0.386	-3.050	0.004

result from the analysis portrays the fact that frequency of medical waste collection is not directly related to the type of the HCF. Activities of the HWM committee in terms of supervision and monitoring should be a direct determinant factor.

Model II establishes the nature of the relationship between awareness of materials being recycled by the hospital and special budget for waste management practice. Result shows that lack of adequate knowledge on waste management practices could be responsible for poor planning and budgeting as observed in many HCFs. A critical observation reveals that a growth of 1% in special budget for waste management could increase awareness among hospital staff by over 40%, having other factors constant.

Thus, the result provides empirical evidence suggesting that increase in the budgetary allocation for waste management would facilitate publicity and awareness creation concerning recycled materials and general waste management practices.

Model III revealed that time of active engagement in health-care services does not determine level of importance attached to waste management and awareness among health-care workers. It is rather, a matter of management decision, value and orientation. Thus, a negative relationship is observed between years of active engagement in the profession and availability of instructive posters on waste segregation around the HCFs. It could be observed that from the empirical result that an active waste management committee set up by

Table 5. Distribution test.

	Type of HCF respondents	Are you aware of any materials being recycled by the HCF?	What is the frequency of collection of medical waste from the wards (times/day)?	How long have you been working in this HCF?	Is there any waste management committee in the HCF?
Chi-Square	35.065 ^a	40.164 ^b	71.273 ^d	110.419 ^b	8.397 ^a
df	2	1	4	4	1
Asymp. Sig.	0.000	0.000	0.000	0.000	0.004
	Is there a manual document on management of hospital waste available in your HCF?	Who is responsible for collecting, handling, storage and disposal of the medical wastes from the wards in the HCF?	How long have you been working in this HCF?		
Chi-Square	26.471 ^a	109.448 ^b	110.419 ^c		
df	1	3	4		
Asymp. Sig.	0.000	0.000	0.000		

the management should be a determinant factor in ensuring proper sensitization and publicity of medical waste management practice. Waste management committee has a significant role in facilitating awareness for waste recycling. Utilization of instructive posters and other informative symbols should be examples of approach and procedures to be adopted.

Model IV informs that proper assignment of roles and responsibilities for collection, handling, storage and disposal of medical waste from the wards should be well driven with utmost compliance. On average, there is assignment of responsibilities for medical waste collection, handling, storage and disposal in some HCFs, but there is no manual or guideline documented. As discussed earlier, this result also points out that the nature and activities of the MWM committee and the level of consideration given to MWM and recycling could account for the ability of HCFs to provide instructive manual or guideline document(s). It is also worth to emphasize here that, apart from the availability of MWM manual or guideline documented, there is also need for strict adherence and compliance to the speculation outlined therein for significant result to be achieved. The evidence from Model V reveals a significant positive impact of special hospital budget for waste management. Further analysis of the result indicates that 1% increase in the level of special budget and allocation for waste management in the hospital could significantly increase the existence and performance of the waste management committee by over 67% in the hospital, all things being equal.

Hence, the following hypotheses were suggested;

H₁: Majority of HCFs in Ota lack proper arrangement for handling and treatment of MW

Model V establishes the relationship between frequency of collection of medical waste and management

committee in the hospital. The result in Table 4 suggests that the presence of hospital waste management committee (if any) do not positively influence the frequency of medical waste collection from the hospital wards per day. Although, the frequency of waste collection invariable could be directly related to the volume of waste production, active engagement by cleaners and other waste management officials, however, the MWM committee should supervise and coordinate the activities of these workers to ensure a quick response to waste disposal, collection, treatment and recycling process. Table 5 presents the distribution test employed to analyze distributional effect of the responses. The chi-square normal distribution and asymptotic significance was utilized to test the distributional effect of the responses and also determine its statistical relevance as it relates to the hypothesis of this study.

H₂: There is inadequate awareness of hospital waste recycling process among medical workers in Ota

The result of the analysis in Table 4 supports the evidence that the different categories of HCFs captured by the survey are well distributed and therefore highly significant. It confirms that majority of the HCFs workers are not aware of any material being recycled by the hospital. The study therefore provides support that among the various types of HCFs surveyed, there is low level of awareness on whether materials are recycled. It also establishes that medical waste from the wards are collected at time intervals per day based on the hospital waste management routine of cleaners or agents responsible for the hospital waste collection and disposal.

H₃: There exist low adoptions of MWM practices in most of the local medical health organizations in Ota

The empirical result emanating from Table 3 also shows

that the surveyed staffs have had some year(s) of experience in active engagement in health-care services. Responses indicating existence of waste management committee are statistically significant. It can be concluded that the responses are from experienced medical personnel and that there exists little or no waste management committee or people charged with the responsibility of handling waste products in majority of HCFs surveyed. It further reveals the probability of having an error in 4 responses out of every 1000 tables as revealed in the chi square normal distribution.

The result of the chi square test is shown in Table 5. Given the degree of freedom at 1, 3 and 4, respectively indicates no associated probability for the occurrence of Type 1 error in 1000 tests. This result shows that on average, there could be negligible Nigerian HCFs with effective manual or document on MWM available in their facility. The result provided significant evidence of people responsible for collecting, handling and disposal of the medical wastes from the wards in the HCFs which consists mostly of the health attendants. Some well experienced medical workers within the various HCFs also confirmed the result of the responses from the administered questionnaire.

CONCLUSION AND RECOMMENDATIONS

The determination of the quantity of medical waste generated in kg/day has been realized and various methods of waste disposal examined. This study has also situated the various levels of training and regulations on the management of medical waste, as well as levels of awareness of medical waste management among health-care workers in selected HCFs in Ota, South West Nigeria.

The HCFs in Ota metropolis, in comparison to the developed nations have minimal appropriate practices when it comes to handling and disposal of these wastes, starting from the personnel responsible for collection and storage through to the final disposal of the wastes. Though regulation exists, but there is no implementation and enforcement. This has made many health-care facility operators to relax. The study has demonstrated that medical waste management in Ota faces many challenges because there had been lack of data on the quantities and nature of the waste generated in previous times which this study has been able to come up with a significant information that could serve as baseline data for other researchers. Such important data are of utmost importance for meaningful planning of waste management procedures. Also, there is no formal policy or directive put in place by stakeholders or government. Currently, the management of infectious waste is normally governed by activities of largely untrained and uneducated waste handlers from poor backgrounds. Collectively, this study indicates important implications for the health of handlers, other health care staff, patients,

their families and indeed entire residents of the community. To this end, the recommendations to improving the management of medical waste in Ota are listed below:

1. A sustained cooperation must be formed among all key actors (government and waste managers) with the purpose of implementing a safe and reliable medical waste management strategy, not only in legislation and policy formation but also in its monitoring and enforcement;
2. All staff and waste handlers in each HCF should be regularly updated with specialized training, which provides updated knowledge about the process of waste management and associated health risks;
3. The mass media should also sensitize the general public and raise their awareness level on environmental risks associated with improper management of medical waste;
4. There is a need for further studies to be conducted on other aspects of medical waste, not covered by this study, so as to generate a comprehensive pool of much-needed baseline data in other local government and Nigeria.

Conflict of interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors are grateful to Messrs Ifeoluwa Ogundeji, David Odey and Kingsley Chinagorom (Class of 2012/2013) of the Department of Civil Engineering, Covenant University, Ota, Nigeria who assisted in administering questionnaire for this study. The authors express profound appreciation to all health personnel of the health care facilities that participated in the exercise for their cooperation and the management of Covenant University for providing enabling environment.

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Full Length Research Paper

Automated classification of coronary artery disease using discrete wavelet transform and back propagation neural network

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Received 9 March, 2014; Accepted 7 May, 2014

An automated classification of coronary artery disease using discrete wavelet watershed transform and back propagation neural network has been proposed which basically segments the blood vessels of the coronary angiogram image as a first step, which in turn involves various stages such as pre-processing, image enhancement, and segmentation using discrete wavelet transform and watershed transform along with morphological operations. Pre-processing is done to remove the noise using the bicubic interpolation method followed by Daubechies 4 discrete wavelet transform and Weiner filtering. Further, image enhancement is done to improve the quality of the image using the histogram equalization technique. Auto thresholding is done to segment the edges of the blood vessel accurately and efficiently using distance and watershed transforms followed by normalization and median filtering. Finally, morphological operations are performed to remove the noise due to segmentation. Features such as area, mean, standard deviation, variance, brightness, diameter, smoothness, compactness, skewness, kurtosis, eccentricity and circularity are extracted from the segmented coronary blood vessel to train the neural network using back propagation network. Thus, the system is able to achieve 93.75% normal classification and 83.33% abnormal classification. Also, 90% efficiency is achieved in classifying Type 1 and 92% efficiency is achieved in classifying Type 2 stenosis at a learning rate of 0.7 and Type 1 classification efficiency of 85% and Type 2 classification of 89% has been achieved for 50 hidden units of the neural network.

Key words: Coronary artery disease, discrete wavelet transform, watershed transform, morphological operations, back propagation neural network.

INTRODUCTION

Medical images such as coronary angiogram images account for a large portion of noise. There is a real challenge to segment such blood vessels. Angiography is

a procedure to observe the blood vessels of a human being and further investigation is carried with the help of angiograms which detects the edges of the blood vessel.

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Blood vessel detection is an important diagnostic concept of image segmentation, which detects the edges of the angiographic blood vessels (Albert, 2006; Rice et al., 2000; Bouchet et al., 2007; Cemil and Francis, 2004; Nain et al., 2004; Lacoste et al., 2006; Brieva et al., 2005; Suri et al., 2002; Nyual et al., 2000; Lorigo et al., 2001; Lo et al., 2006; Sarry et al., 2001; Hassouna et al., 2003; Wink et al., 2004; Saha et al., 2000; Rafael et al., 2002; Chan et al., 2000; Espin et al., 2004; Zhou et al., 2006).

Jean et al. (2008) have used the application of minimal surfaces and Markov random fields as models and applied to the region adjacency graph of the watershed transform to segment the liver tumors. The researcher attempted to segment the relevant tumors from the liver image. Although the researcher did not segment the blood vessels of the angiogram image, but it is understood that unsupervised watershed transform along with Markov model is applied. Jayadevappa et al. (2009) developed a hybrid segmentation model based on Watershed and Gradient Vector flow (GVF) for the detection of the brain tumor. Generally the GVF suffers from a very high computational requirements and sensitive to noise. These are overcome by the integrated method which makes use of the watershed algorithm.

Ning et al. (2007) proposed a new algorithm which combines the watershed transform (Nassir, 2005) and level set method in order to extract the accurate boundary of the vessels. The researcher demonstrated the cost time which mainly depends on the number of pre segmented regions. However, performance of the system could be improved only if some prior information and distinguishable features are included and the researcher did not carry any performance evaluation. Pinaki and Dibyendu (2012) proposed an easy and simple method to overcome over segmentation by using the distance transforms and image smoothing of the morphological techniques (Sun et al., 2007; Deng and Heijmans, 2002; Tsair et al., 2009, 2003; Wong et al., 2005; Weili et al., 2010) along with watershed for segmentation. Plot with the number of pixels before and after smoothing was done to prove the performance of the system and testing was performed only on color images and not on medical images which is one of the limitations.

Ishita and Monisha (2012) proposed a new method for brain tumor segmentation using watershed (Jean et al., 2008) and edge detection algorithm in HSV color model. Initially the RGB image is converted into HSV color image and watershed algorithm is applied to each region after contrast enhancement which is then followed by canny edge detection. Finally all the three images are combined to get the segmented image. However, the performance of the system was not evaluated using any parameter. Yugander and Sheshagiri (2012) developed an improved watershed algorithm and modified level set method. The over and under segmentation problems were overcome by using dual tree complex wavelets and modified watershed based on Wasserstein distance. This method

was used to extract the finger print from the original image and not for segmentation of the blood vessels and the performance of the system was not evaluated. Also, the system involves complex wavelets which itself is complex.

Qing et al. (2004) and Li et al. (2006) evaluated the performance of the watershed algorithm by analyzing the binary images and comparing them against different distance transforms. The researcher concluded that the Watershed algorithm is very effective for grey level segmentation of medical images. The researcher concluded that the chessboard distance transform performed well as against the Euclidean distance. Ghassan et al. (2009) pointed out that although watershed transformation is generally used for segmentation it is limited due to over segmentation and sensitivity to noise. However, these drawbacks were overcome by enhancing the prior shape and appearance knowledge. The problem of over segmentation was overcome by using clustering namely k-means segmentation and noise is removed or suppressed by computing the mean intensity of each segment. However, the researcher did not evaluate the performance of the system proposed and it involves complex algorithm.

Nassir et al. (2006) has combined K-means clustering, watershed and difference in strength (DIS) for segmentation. Although the proposed method overcomes the over segmentation there is no valid performance evaluation done. Zulong and Kaiqiong (2010) used contour based segmentation which in turn uses the morphological operations (Qing et al., 2004; Chan et al., 2000; Shoujun et al., 2009; Sidahmed et al., 2013) were used to detect the edges rather than using the gradient or gray level intensity, whereby the problems due to inhomogeneity is overcome. However, the researcher did not carry any coronary quantitative or statistical analysis to prove the efficiency of the system (Hernandez et al., 2000; Morteza et al., 2011; Schrijver et al., 2002; Pascal et al., 2006; Yan et al., 2005; Kobashi et al., 2000; Mukhopadhyay et al., 2003; Zhou et al., 2008; Chan and Vese 2001; Law et al., 2001; Yu, 2002).

Chih-Yang and Yu-Tai (2005) introduced the extraction of coronary angiogram blood vessels from the digital angiographic images. The researchers used three important steps to segment or extract the coronary angiogram blood vessel, they are namely, background elimination and noise removal, blood vessel enhancement and blood vessel segmentation from the coronary angiogram image. In the first stage, the researcher applied a temporal fourier transform followed by a high pass temporal filtering, which allows only the low-frequency terms, followed by inverse fourier transform. The transformed image so formed will not have any unwanted background, however, contains some spikes or noise, which may be due to isolated noise which cannot be detected and removed by using the fourier transform as it is based on the pure frequency

domain. Hence to remove the isolated noise Discrete Wavelet Transform (DWT) (Ali et al., 2009; Elly, 2011; Jorge et al., 2003; Yu, 2002; Zulong et al., 2010; Tang et al., 2006) is applied. A three level decomposition was employed and the LLL sub-band region will consist of the features pertaining to the blood vessel. Thresholding is applied to preserve the edge information and finally Inverse Discrete Wavelet Transform (IDWT) is applied.

In the second stage, blood vessel enhancement is done using 72 matched filters (Hoover et al., 2000) and is projected onto the xy plane, followed by blood vessel segmentation, based on clustering analysis using a stencil mask. Further, histogram analysis is carried with thresholding and 18-adjacency clustering to segment the coronary angiogram blood vessel. The method used is very complicated involving two transforms, 72 matched filters, masking and thresholding. Also, the overall execution time was less than 3 min. However, the researcher did not carry any coronary quantitative or statistical analysis to prove the efficiency of the system.

Wenwei et al. (2010) proposed new segmentation method which is based on the transition region extraction (Liang et al., 2001). The researcher used 6 Gaussian matched templates to basically enhance the input coronary angiogram image followed by local complexity method. Segmented image was obtained by applying thresholding to the histogram of the transition region (Yao et al., 2008; Rivest, 2004; Socher et al., 2008; Shoujun et al., 2009) which outperformed the top-hat method. However, the researcher neither did not carry any coronary quantitative or statistical analysis to prove the efficiency of the system nor computed the overall execution time.

Santhiyakumari and Madheswaran (2010) have proposed a method to categorize the carotid artery subjects into normal and diseased subjects namely, cerebrovascular and cardiovascular diseases. For each and every pre-processed ultrasound carotid artery image, contours are extracted using contour extraction techniques. Multilayer Back Propagation Network (MBPN) system has been developed for categorizing the carotid artery subjects. The obtained results showed that MBPN system provides higher classification efficiency, with minimum training and testing time.

Sidahmed et al. (2013) have proposed an algorithm to produce a 85.5% classification accuracy in the diagnosis of Coronary Artery Disease (CAD), in which Genetic Algorithm (GA) generates in each iteration a subset of attributes that will be evaluated using the Bayes Naïve (BN) based feature selection in the second step of the selection procedure. Thus, the assest of the algorithm is then compared with the Support Vector Machine (SVM), Multi-Layer Perceptron (MLP) and C4.5 decision tree algorithm. The results of classification accuracy for those algorithms are 83.5, 83.16 and 80.85% respectively.

Brieva et al. (2005) evaluated four segmentation algorithms for coronary angiogram images. The four algorithms were namely wavelets, snakes, level sets and

dynamic threshold (Masoomah et al., 2009; Mohammed et al., 2011). Here, a multi-resolution wavelet method was employed which consists of filter banks in turn consisting of one dimensional wavelet functions. A set of five filters are applied and segmented based on thresholding. The researcher used mean specificity and mean sensitivity for evaluating the performance of the system. However, the researcher did not carry any other coronary quantitative or statistical analysis to prove the efficiency of the system nor computed the overall execution time. Thus, the system looks complicated with filter banks and set of five filters.

PROPOSED METHOD

From the literature review discussed in introduction, it is clearly evident that the limitations of the watershed algorithm are overcome by enhancing various other techniques from the literature. Also, it is found that the watershed algorithm along with some other techniques is used for the segmentation of medical images such as liver, retina and brain, but is not done for the angiographic images of the heart. In the literature, the researchers have used wavelet discrete transform for suppressing noise and to get more information on the edges of the medical image for segmentation. Thus, the proposed method integrates the watershed algorithm and discrete wavelet transform (Tsair et al., 2009, 2003) which overcomes the limitations of the watershed algorithm along with the morphological operations and drawbacks mentioned in the introduction. Furthermore, it automatically classifies the segmented image into stenosis Type 1 or 2 CAD using the back propagation neural network.

Figure 1 shows the flow diagram of the automated classification of the integrated segmented blood vessel. The proposed automated classification and integrated coronary angiogram image segmentation algorithm using the Discrete Wavelet transform and Watershed Transform (DWWSHD) consists of five major steps, namely:

- Step 1: Image pre-processing
- Step 2: Image enhancement
- Step 3: Image segmentation
- Step 4: Feature extraction
- Step 5: Classification of CAD

(i) Image pre-processing

In this step, first the given coronary angiogram image is resized to 256 x 256. Then, pre-processing is done using the following steps as shown in Figure 2 to produce sharper images of the input coronary angiogram image. Also, it removes noise acquired in the angiogram image.

Bicubic interpolation method

In order to produce sharper input coronary angiogram images, the bicubic interpolation method is adopted in the pre-processing stage. In the bicubic interpolation method the output pixel is obtained as a weighted average of the pixels in the nearest 4-by-4 neighbourhood followed by noise removal and background elimination.

Discrete wavelet transform

Wavelet transform is taken to extract the features initially. After pre

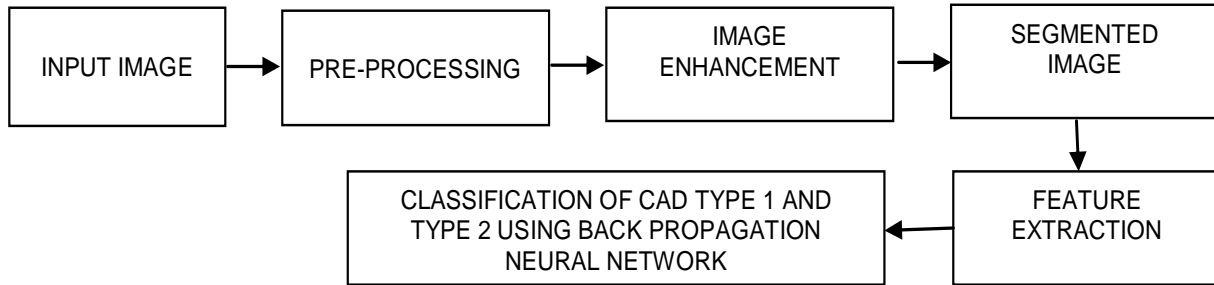


Figure 1. Proposed automated classification method.

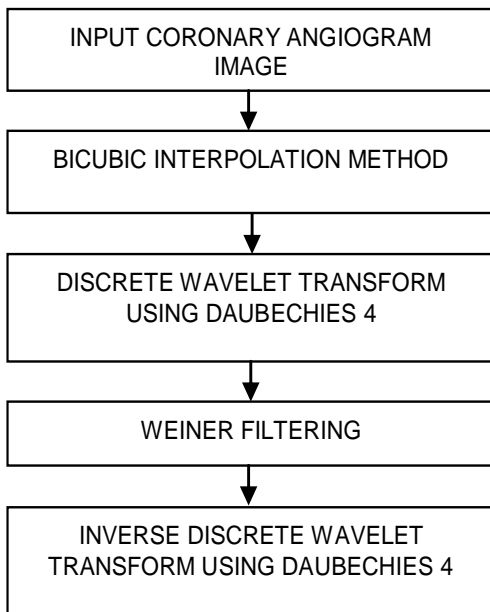


Figure 2. Image pre-processing.

processing, the coronary angiogram images do contain some noise or spikes, which are due to the presence of the isolated noise. These noises are usually not detected and removed by the frequency domain filters or fourier transforms. Hence a wavelet transform is applied after pre-processing which is done to remove the noise.

The DWT is applied to divide the given Coronary Angiogram Image (CAI) into four bands, the Low Low [LL], Low High [LH], High Low [HL] and High High [HH] band. The DWT decomposes the given image based on the scale wavelet coefficients, which represent the noisy signals of the image contained in all the bands except the LL, which retains the features or the edge information of the coronary angiogram image.

A wavelet transform normally consists of a pair of high pass and low pass filters as shown in Figure 3, which are used to decompose the given coronary angiogram image into the low frequency and high frequency components respectively, according to the different number of levels. The decomposed coronary angiogram image is further down (D) sampled by 2 to get the approximation coefficients (cA) and detailed coefficients (cD), which are said to be called as the DWT wavelet coefficients. However, the image can be reconstructed again using the Inverse Discrete Wavelet Transform (IDWT), which is so called as the reconstruction process. Normally,

the input coronary angiogram image is divided into four regions, namely:

- (a) LL – This sub band is obtained by using two low-pass filters,
- (b) LH and HL – These two sub bands are obtained by using one low-pass filter and one high-pass filter, and
- (c) HH – This sub band is obtained by using two high-pass filters.

After the first level of decomposition, the LL sub band is decomposed again using the same pair of low-pass filter and high-pass filter to perform n-stage discrete wavelet transform. Thus scale based decomposition is obtained by the wavelet transform in which the noise is represented by the finer scaled wavelet coefficients. The LL sub band does not contain any noise while all other sub bands do contain noise. However, the coefficients of such scales represent the edge information, which must be maintained by selecting a threshold to remove the noise. Thus, the unwanted noise is removed while the important local features of the coronary angiogram blood vessel is retained that is, the edge information is preserved.

In the proposed integrated method, the Daubechies 4 discrete wavelet transform (Elly, 2011) is applied with periodization to the coronary angiogram image. It produces the smallest length wavelet decomposition and the same mode of periodization is applied for IDWT to ensure perfect reconstruction. The Daubechies 4 wavelet transform is comparatively distinct from Haar wavelets because the scaling signals and wavelets produced are due to average's and differences from the signals. It conserves the signals energy and redistributes in a compact form.

Weiner filtering

Usually interpolation tends to increase the mean square error and hence in order to minimize it, the Weiner filtering approach is employed. It performs very well on the edges of the given coronary angiogram images, which is applied before taking the IDWT and after the DWT. Thus Weiner filtering is used to detect the edges of the given coronary angiogram blood vessel.

Algorithm

- (a) Perform the DWT of the given input coronary angiogram image.
- (b) Preserve the edge information of the LL band by applying Weiner filtering.
- (c) Perform IDWT of the modified image from step b.

This produces the edge enhanced image, which is sharper than the original input coronary angiogram image in which more details can be seen clearly. Thus, the Daubechies 4 wavelet transform is used to preserve the edge and detailed visibility information, which is the

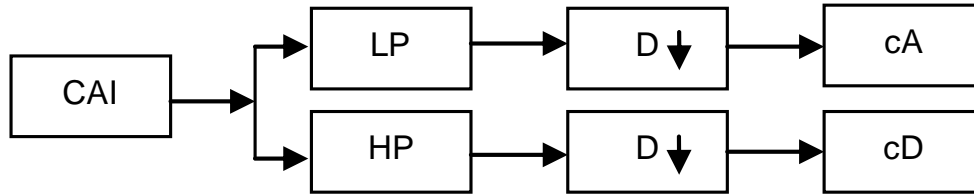


Figure 3. Single level wavelet decomposition.

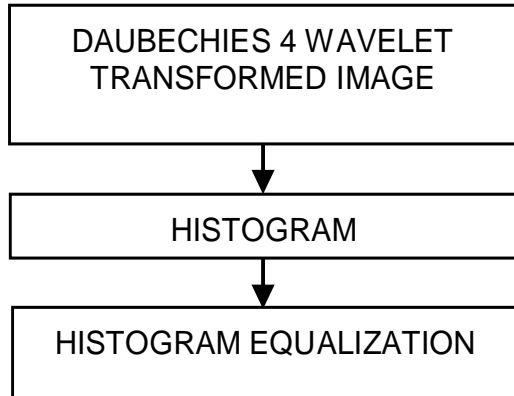


Figure 4. Image enhancement.

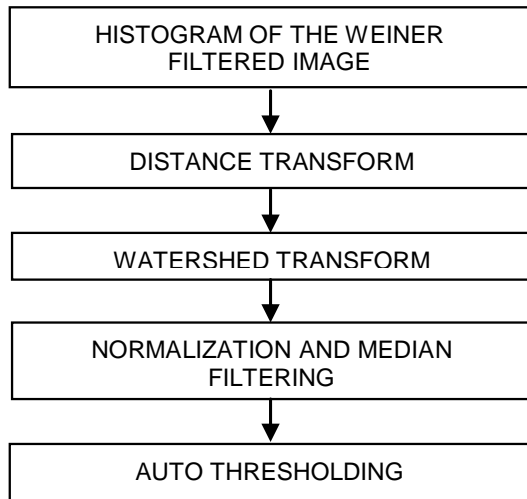


Figure 5. Auto thresholding.

fundamental importance in medical and biological coronary angiogram image.

(ii) Image enhancement

Next take histogram of the Weiner filtered wavelet transformed coronary angiogram image and perform histogram equalization technique as shown in Figure 4. The following conditions are set to perform histogram equalization:

For pixels ≤ 100 , equalized to 50
 For pixels ≤ 170 , equalized to 128
 For pixels ≤ 220 , equalized to 190
 Else, 230

(iii) Image segmentation

Image segmentation is done after image enhancement followed by applying watershed transform and auto thresholding. The detailed algorithm implemented is shown in Figure 5.

Auto thresholding algorithm

Step 1: Histogram is performed to determine the threshold value in order to segregate the coronary angiogram blood vessel from the background.

Step 2: Obtain the texture colored image.

Step 3: Compute the true Euclidean distance transform of the binary image. The distance transform assigns a number to each pixel of the given image which is the distance between that pixel and the nearest non-zero pixel of the given image.

The Euclidean distance (Qing et al., 2004) between two pixels (x_1, y_1) and (x_2, y_2) is defined as in Equation (1),

$$d_{euclidean}(x, y) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

Step 4: Next compute the distance transform of the complement of the binary image.

Step 5: Compute the distance transform and force the pixels which do not belong to the edges to be at infinity.

Step 6: Compute the watershed transform and display the resulting label matrix as an RGB image.

Assuming that the image f is an element of the space $C(D)$ of a connected domain D , then the topographical distance between points x and y is given as in Equation (2),

$$T_f(x, y) = \inf_{\gamma} \int |\nabla f(\gamma(s))| ds \quad (2)$$

Where, 'inf,' is the overall paths inside D . Thus, let $f \in C(D)$ have a minima $\{m_k\}_{k \in I}$, for some index set I . The catchment basin $CB(m_i)$ of a minimum m_i is defined as the set of points $C \in D$, which are topographically closer to m_i than to any other regional minimum m_j and is given by Equation (3).

$$CB(m_i) = \{x \in D \mid \forall_j \in I \setminus \{i\} : f(m_i) + T_f(x, m_i) < f(m_j) + T_f(x, m_j)\} \quad (3)$$

Thus, the watershed (Javadevappa et al., 2009) is the set of points which do not belong to any of the catchment basin as shown in Equation (4);

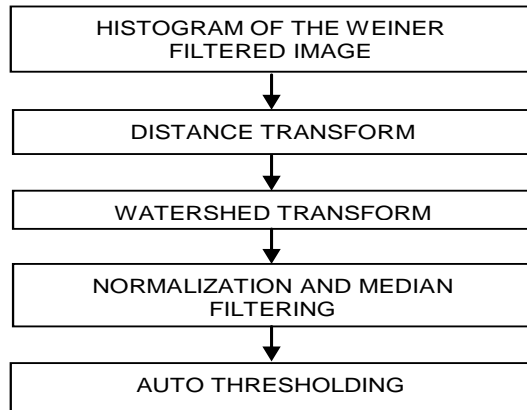


Figure 5. Auto thresholding.

$$W_{shed}(f) = D \cap \left(\bigcup_{i \in I} cB(m_i) \right) \quad (4)$$

Step 7: Perform normalization and median filtering. Perform image subtraction to eliminate the background of the given image. This is done by subtracting each element in the array y from the corresponding element in an array x of the given array (x,y) and then the difference between them is returned to the output array z .

Step 8: Perform intensity adjustment. This performs a mapping between the input image and output image based on intensity. Intensity values below L_{in} are mapped to L_{out} , intensity values above H_{in} are mapped to H_{out} , and values between L_{in} and H_{in} are mapped to values between L_{out} and H_{out} .

Step 9: Finally, auto thresholding is performed using the ISODATA method.

ISODATA method is used to perform auto thresholding which uses iterative technique. In this method, a global threshold is computed which is used to convert the intensity image to a binary image and is a normalized intensity value that lies in the range $[0, 1]$. This iterative technique was developed by Ridler and Calvard (1978). The histogram is initially segmented into two parts using a starting threshold value such as zero equal to half the maximum dynamic range. The sample mean ($m_f, 0$) of the gray values associated with the foreground pixels and the sample mean ($m_b, 0$) of the gray values associated with the background pixels are computed. Thus, a new threshold value 1 is now computed as the average of these two sample means. This process is repeated based upon the new threshold until the threshold value does not change any more.

Isodata algorithm

Step 1: Compute the mean intensity of the given image from the histogram H .

Step 2: Compute the Mean above H (MAH) and Mean below H (MBH) using H from step 1.

Step 3: New $H = [MAH+MBH]/2$

Repeat step 2 if $H(i) \approx H(i-1)$, Normalize the threshold to the range $[i, 1]$

Level = $(Th-1)/(n(end-1))$

Morphological operations

Finally morphological operations are performed to segment the detected edges of the coronary angiogram image. First remove the

interior pixels by setting a pixel to '0', if all its 4-connected neighbours are 1, thus leaving only the boundary pixels ON. Then remove the isolated pixels such as the individual 1's surrounded by 0's and also remove the H-connected pixels as these do not contribute to the edges of the coronary angiogram blood vessel. Generally a median filter is employed when the goal is to simultaneously reduce noise and preserve edges. Here each output pixel contains the median value in the m by n neighbourhood around the corresponding pixel in the input image. Thus, the blood vessels of the given coronary angiogram image is segmented using the integrated method of Discrete Wavelet transform and Watershed Transform (DWWSHD) along with the morphological operations.

(iv) Feature extraction

After segmentation feature extraction is done. From the segmented coronary angiogram image, features such as area, mean, standard deviation, variance, brightness, diameter, smoothness, compactness, skewness, kurtosis, eccentricity and circularity are extracted to train the neural network

(v) Classification of CAD using BPN

The classification of CAD using neural network basically consists of the following steps:

Step 1: Extracted feature transformation

Step 2: Network architecture definition

Step 3: Learning algorithm

Step 4: Validation

In the first step, the extracted features of section D are given to the neural network for recognition of particular patterns. In the second step, the number of neurons in each layer, and the number of hidden layers are defined. Also, the connectivity between each layer is defined. Usually, the number of input neurons, hidden neurons and output neurons depends on the problem studied. The network may not have required degrees of freedom to learn the process correctly, if the numbers of hidden neurons are small and vice versa.

In the third step, a learning algorithm is used to train the network to respond correctly to a given set of inputs. Normally, the neural network is said to be well trained when there are more input data's available. It is possible to determine the weights through training, in which initially the weights are assigned to be random or based on experience. Thus, in the process of the learning algorithm, the network is said to change the weights systematically in order to perform the desired input output relation properly. In the fourth step, the validation is done in order to evaluate the performance of the system trained. The back propagation algorithm is given as below for the classification of the type of coronary artery disease.

Step 1: Read the number of layers and number of nodes in each layer

Step 2: Initialize the weights

Step 3: Read the pattern

Step 4: Calculate the number of output nodes in each successive layer

Step 5: Calculate the mean square error for a pattern

Step 6: Calculate the momentum of a node in the output node

Step 7: Update the weights between layers

Step 8: If the weights are not updated for all the layers, then calculate the momentum of a node in the hidden layer and repeat step 7

Step 9: Then calculate the mean square error for all the patterns

Table 1. Confusion matrix of the back propagation neural network.

S/No	Desired output	Classified normal	Classified abnormal
1	Normal	30	3
2	Abnormal	2	15

Table 2. Percentage of Correctness for the back propagation neural network.

S/No	Desired output	Classified normal	Classified abnormal
1	Normal	93.75	16.67
2	Abnormal	6.25	83.33

Step 10: If not go to step 3

The learning algorithm depends on three main parameters, namely, the learning rate, momentum, and the mean square error. The learning rate usually determines the change in the size of the weight, while momentum causes the weight changes to be dependent on more than one input pattern. Mean square error is the value at which the network error dips below a particular error threshold.

The two types of the CAD diseases are defined as Type 1 and 2 diseases. Type 1 disease is called eccentricity, in which the atherosclerotic plaque is not distributed along the entire circumference, leaving a variable arc of disease free wall. Type 2 disease is called concentric, in which the atherosclerotic plaque is distributed along the entire circumference of the internal elastic membrane.

EXPERIMENTAL RESULTS

The proposed algorithm was tested on the images acquired from 50 patients. The proposed algorithm was implemented and tested in MATLAB 7.0 on a Pentium IV Personal Computer (with Central Processing Unit 2.8G and 512 memory). The performance of the automated classification of CAD using back propagation network is evaluated using the following parameters:

- Confusion matrix
- Learning rate
- Hidden units

Testing of the back propagation neural network is done after the training phase. The data that are not trained by the network, is applied to the neural network to evaluate its performance. Table 1 shows the confusion matrix for the result classification between normal and abnormal for this neural network. It is observed that two normal samples are classified incorrectly by the neural network as the subjects do not have either Type 1 or 2 coronary artery disease. Also, three abnormal samples are incorrectly classified as normal although the subjects do have coronary artery disease. The confusion matrix can also be expressed as percentage of correctness as shown in Table 2.

From Table 2, it could be observed that according to the percentage of correctness, the normal samples are classified correctly by the neural network with 93.75% of correctness and incorrectness by 6.26%. Persons who are having coronary artery disease are correctly classified with 83.33% while incorrectly classified with 16.67%. Thus, accuracy of classifying normal persons and abnormal persons are 93.75 and 83.33%. The performance of the back propagation neural network for various learning rates ranging between 0.1 to 1.0 is observed as shown in Table 3. The training is done with 50 coronary angiogram images. From Table 3, it is observed that the average training time ranges from 2.36 to 1.98 s and the average testing time ranges from 0.0142 to 0.0088 s for the learning rate varying from 0.1 to 1.0 in steps of 0.1. Also, the Type 1 classification efficiency is 90% and Type 2 classification efficiency is 92% at a learning rate of 0.7 which is said to be the optimum learning rate. The corresponding average training time is 2.18 s and average testing time is 0.0105 s.

From Table 4, it is observed that the objective of the network is not met upto hidden units of 30, beyond which it is achieved. The maximum classification efficiency for Type 1 and type 2 are 85 and 89% at 50 hidden units with an average training time of 1.93 s and average testing time of 0.0156 s. Thus, the application is said to have one hidden layer with fifty hidden units. From Table 5 it can be seen that the accuracy of classifying the CAD using DWT and BPN automatically by the proposed method is 89%, which is predominant as compared to the other methods specified in the literature.

SIMULATED RESULTS

The simulated results are shown in Figures 6 to 7 for both the proposed automated classification of CAD using BPN. Only two input images and its superimposed output coronary angiogram images along with its classification of CAD type are shown for simplicity. Figure 6 shows the input coronary angiogram image which is tested for the Type 1 CAD. Figure 7 shows the region properties

Table 3. Average training time, average testing time and classification efficiency for different learning rate.

S/No	Learning rate	Average training time (s)	Average testing time (s)	Classification efficiency (%)	
				Type 1	Type 2
1	0.1	2.36	0.0142	84	82
2	0.2	2.33	0.0138	79	80
3	0.3	2.30	0.0138	82	80
4	0.4	2.29	0.0125	85	87
5	0.5	2.23	0.0117	80	82
6	0.6	2.20	0.0116	82	83
7	0.7	2.18	0.0105	90	92
8	0.8	2.14	0.0103	82	84
9	0.9	2.11	0.0098	77	78
10	1.0	1.98	0.0088	75	76

Table 4. Average training time, average testing time and classification efficiency for different hidden units.

S/No	No. of hidden units	Training status	Average training time (s)	Average testing time (s)	Classification efficiency (%)	
					Type 1	Type 2
1	5	Not met	-	-	-	-
2	10	Not met	-	-	-	-
3	15	Not met	-	-	-	-
4	20	Not met	-	-	-	-
5	25	Not met	-	-	-	-
6	30	Not met	2.48	0.0192	65	68
7	35	met	2.22	0.0184	69	68
8	40	met	2.18	0.0175	73	75
9	45	met	2.10	0.0166	77	78
10	50	met	1.93	0.0156	85	89

Table 5. Percentage of correctness for the back propagation neural network.

S/No	Methods	Accuracy (%)
1	Crisp rule based classifier (Markos et al., 2008)	58.3
2	Adaptive Neuro Fuzzy Inference system (Markos et al., 2008)	56.8
3	Optimized Fuzzy Model (Markos et al., 2008)	73.4
4	Artificial Neural Network Method (Markos et al., 2008)	73.9
5	Fuzzy Support decision system (Noor et al., 2009)	87
6	Proposed method	89

stages, Figures 8 and 9 shows the features extracted and the extracted blood vessel. Figure 10 shows the training of the neural network and Figure 11 shows the testing phase, while Figure 12 shows the superimposed image and classified Type 1 CAD by Figure 13. Figure 14 shows the input coronary angiogram image which is tested for the Type 2 CAD along with the extracted blood vessel. Figure 15 shows the training of the neural network and Figure 16 shows the superimposed image and classified Type 2 CAD by Figure 17.

Conclusion

It is concluded that the automated classification of coronary artery disease using the back propagation neural network has yielded a 93.75% normal classification and a 83.33% abnormal classification by integrating the discrete wavelet transform and watershed algorithm along with morphological operations. Also, Type 1 classification efficiency of 90% and Type 2 classification of 92% has been achieved at a learning rate

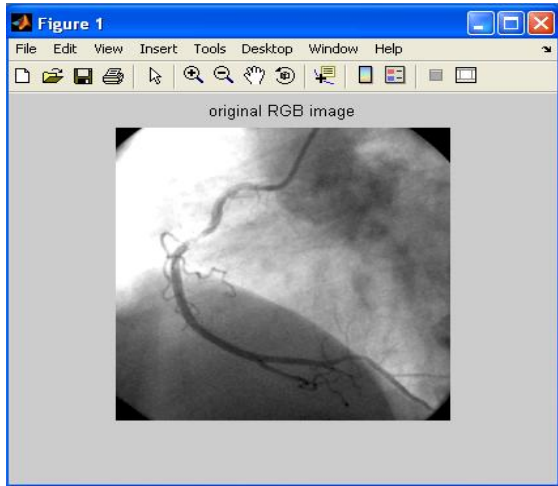


Figure 6. Input coronary angiogram image.

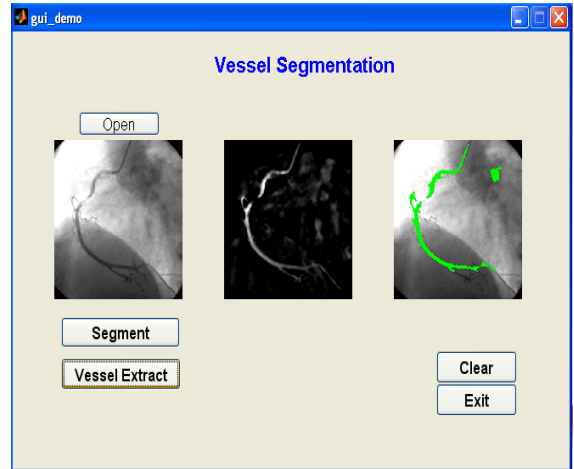


Figure 9. Extracted coronary angiogram of type 1 CAD.

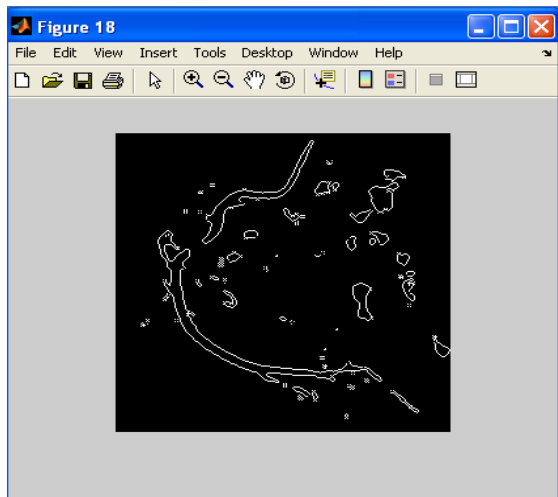


Figure 7. Region properties stages.

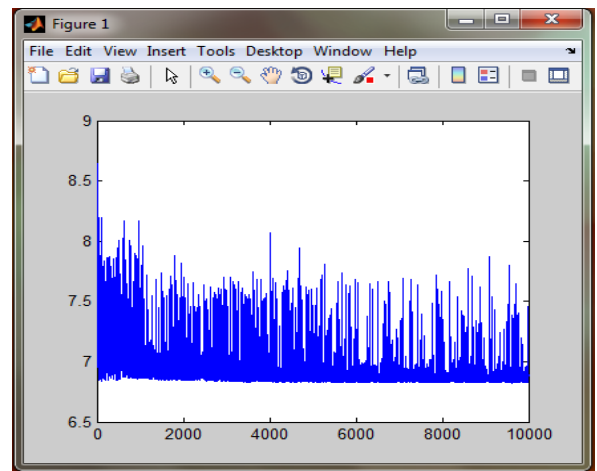


Figure 10. Training process for Type 1 CAD.

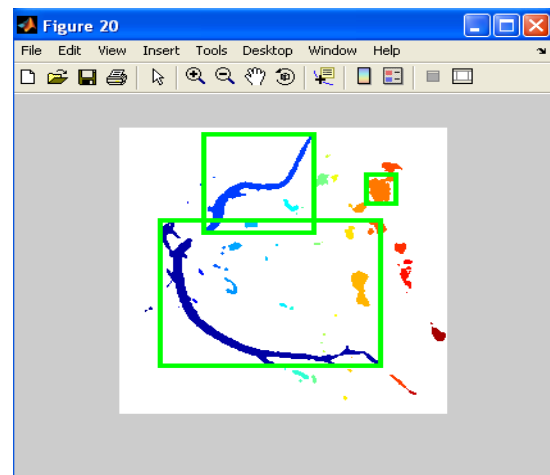


Figure 8. Feature extraction.

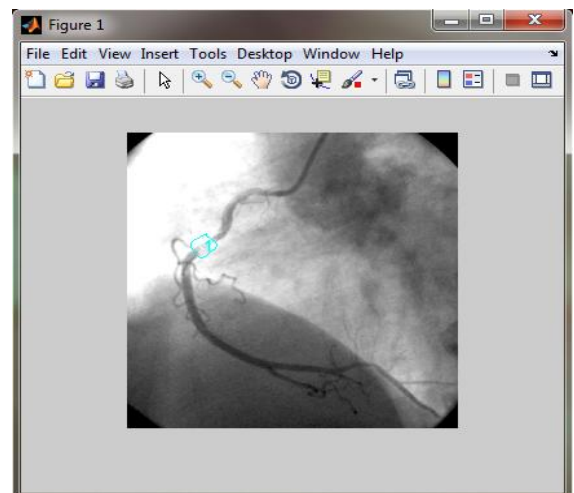


Figure 11. Testing process for Type 1 CAD.

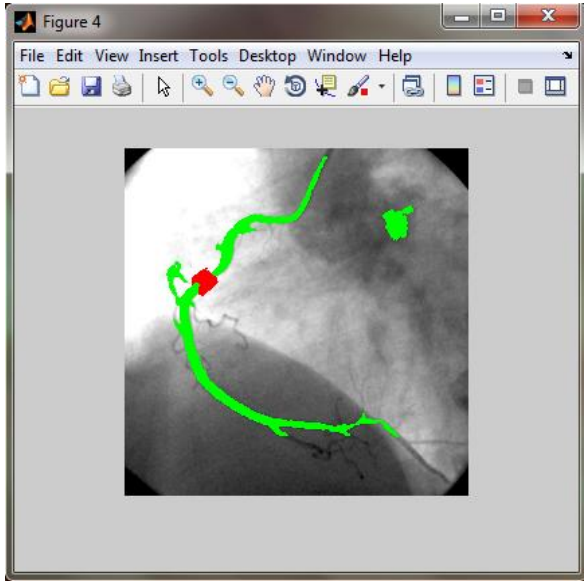


Figure 12. Superimposed image for Type 1 CAD.

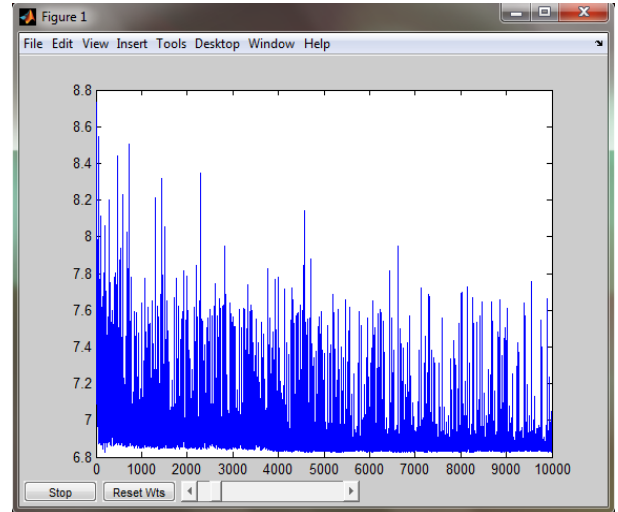


Figure 15. Training process for type 2 CAD.

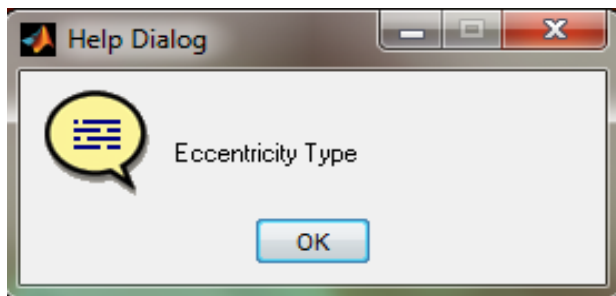


Figure 13. Type 1 CAD classified.

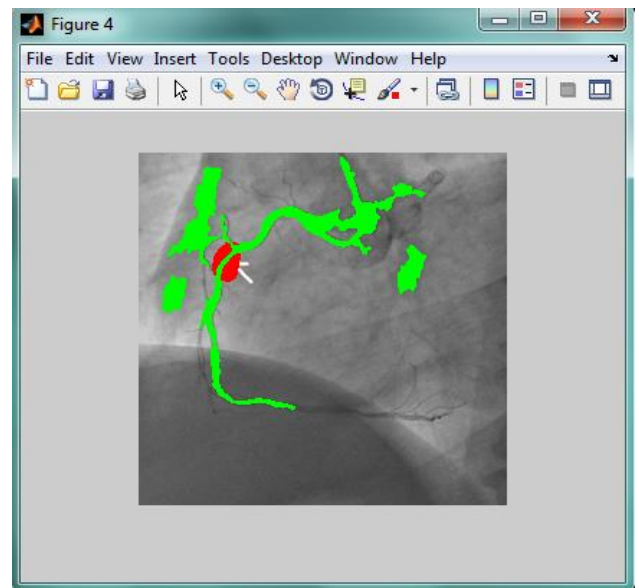


Figure 16. Superimposed image for type 2 CAD.

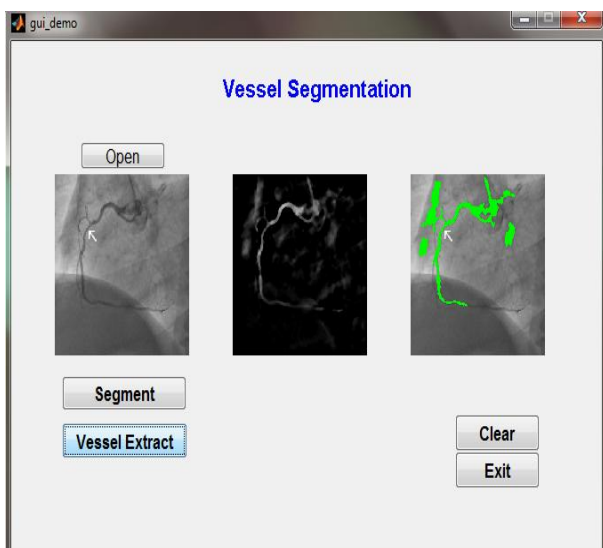


Figure 14. Extracted coronary angiogram of type 2 CAD.

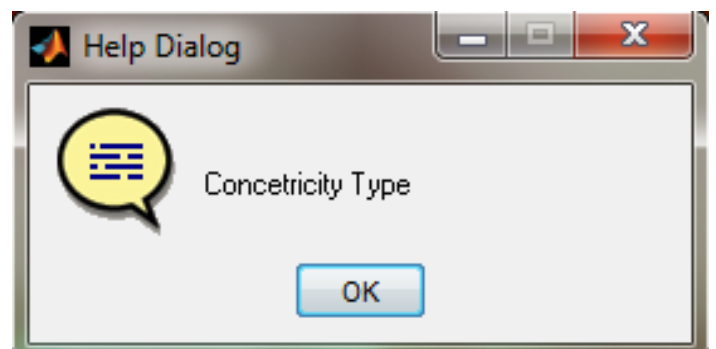


Figure 17. Type 2 CAD classified.

of 0.7 and Type 1 classification efficiency of 85% and Type 2 classification of 89% has been achieved for 50 hidden units of the neural network. An accuracy of 89% in classifying the CAD using DWWT and BPN automatically is achieved, which is predominant as compared to the other methods specified in the literature.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Generation and simulation of new transmission control protocol (TCP) agent over network simulator 2 (NS-2) platforms

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Received 31 December, 2013; Accepted 2 April, 2014

Transmission Control Protocol (TCP) is the most popular protocol used over the wired and wireless networks, and it still has a practical problem where the congestion control mechanism does not permit the data stream to get complete bandwidth over the existing network links. To solve this problem, many TCP protocols have been introduced with high speed performance. The work provided in this article is based on using the Network Simulator 2 (NS-2) to implement a new proposed TCP called "Sumer" TCP. The proposed TCP is based on the same characterizations of Reno TCP, such as congestion control, sliding window and other Reno mechanisms and features. The process of creating new TCP agent over the platforms of NS-2 requires a lot of modifications, files generation, and agent identification to make the new agent recognizable by NS-2 resources. The proposed TCP is developed for scientist and researchers to be easy for them to add the new mechanisms such as slow-start and congestion avoidance with other extra features.

Key words: Transmission Control Protocol (TCP), Sumer TCP, Reno, congestion control, congestion window, NS-2

INTRODUCTION

Transmission Control Protocol (TCP) is a basic communication language, and a connection oriented protocol tied with transport layer that consists of collection of rules and procedures to control communication between links (Abed et al., 2011a). There are many TCP variants that modified and developed respectively with the communications needs. Most TCP present forms include set of algorithms built to control the congestion in critical links of network while maintaining the network throughput. In current years, TCP has been faced with the fast growth in internet in parallel with the increasing demand to

transfer the media on high speed links supported TCP. In the last years, computer networks and mobile cellular systems have qualified incredible evolution and a lot of computers and other user equipment's become linked together with most mutual protocol stack used being TCP. Currently, it is hard to recognize the congestion control mechanisms that are applied by different engines in Internet. One more imperative problem is the manner that these mechanisms are employed in diverse operating systems (Abed et al., 2011b). The greatest universal transport protocol involved is the TCP and in the original

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accomplishment of TCP, a very small number of variants were done to minimize the congestion in network path. Additionally, TCP employment uses accumulative confident acknowledgements and the expiration of a retransmission timer to afford reliability based on a modest go-back-n model. TCP implements various techniques that use proficiently the network resources by approximating the conditions and the characteristics of network. Also, TCP is built on the concept of self-clocking technique where this concept based on several characteristics. TCP has become the key factor in manipulating the behavior and performance of the networks. The TCP congestion control plays a vital role in controlling the applications that request the services over various networks. Furthermore, the congestion control provides the amount of traffics that can be inserted into the network, where it overrides the behavior and the performance of the communications processes.

TCP MODELING IN NS-2

The network simulator NS-2 is a free-access and object-oriented with discrete-event network simulator (NS-2, 1989). NS-2 provides a structure for constructing a network prototype and identifies data as input parameters, analyzing data output and giving outcomes and results. Two main reasons for the wide impact of NS-2 are as follows, the first is because it is free, where that fits researchers in laboratories and universities, and the second reason is the huge range of network modules and objects that can be implemented by NS-2 (Olsén, 2003). This article is used to provide user interfacing that permits the specified input of the model (Tcl scripts) to be executed. Mostly, the elements of any network topology in NS-2 are established as classes in object oriented style. For TCP modeling, NS-2 offers significant support for TCP simulating, modeling, queuing algorithms, routing algorithms, and multicast protocols. Modeling of TCP in NS-2 was initially based on the source code of the BSD kernel (Berkeley Software Distribution) in the 1990s (Wei and Cao, 2006). Later, the TCP modules in NS-2 have extremely assisted the research teams and groups to evaluate and investigate the behavior of TCP where that led to the expansion in developing many congestion control techniques. Two categories of TCP are available in NS-2. The first category is a one way TCP, where it uses objects with several classes on sides, sender and receiver. On the TCP sender side, some available classes are provided for TCP Tahoe, Newreno, Reno, Vegas Sack, and Fack. While in the side of receiver, the classes available for TCP are both without delayed and with selective acknowledgements. Furthermore, other subclasses can be derived from these provided classes to apply the required modifications to the standard congestion control mechanisms. The second category includes two ways TCP, where the TCP uses objects with

the same class on sender and receiver sides. The NS-2 is written using C++ as a programming language, with an OTcl interpreter shell (Tcl is a script language with Object-Oriented extensions Tcl: Tool Command Language). Figure 1 show the code structure of TCP Linux in NS-2 where TCP Linux is an experimented TCP created by Wieand Cao (2006).

The whole modules include four parts, corresponding to the four white blocks in Figure 1. The yellow blocks are from outside source codes such as NS-2 or Linux (Wie and Cao, 2006). TCPLinuxAgent (in tcp-linux.h and tcp-linux.cc): this is the main component which loosely follows the Linux implementation in packet receiving, ack processing and congestion control. ScoreBoard1 (in scoreboard1.h and scoreboard1.cc): this is a new packet SACK/Loss/Retransmission control module which combines Scoreboard-rq in NS-2 and Linux's ACK/SACK processes. It loosely follows the steps in tcp_clean_rtx_queue and tcp_sacktag_write_queue in tcp_input.c in Linux. The interface between NS-2 and Linux (in linux/ns-linux-util.h and .cc): this part redefines the data structure in Linux TCP and provides interfaces between the NS-2's C++ code and Linux's C code. Shortcuts for other Linux system calls (in linux/ns-linux-c.h and .c): this part redefines many system calls in Linux (to void) and allows Linux source code to be compiled with very minor changes.

In Figure 2 we can see that the NS-2 design uses a model named shared object design where this means that the NS-2 system is based on programming in two languages and with these two languages there is a corresponding hierarchy of the network objects, but the object in one are open to the other and also there is an object accessible to one portion of the system where this is basically for an efficiency purpose. NS-2 uses C++ to write and compile the network components in the data path to reduce the packet and the required time for processing. The objects compiled by the NS-2 system are made to exist to an OTcl interpreter over an article linkage.

This linkage generates an equivalent OTcl object for each C++ object and creates the configurable variables identified by C++ objects to affect as an associated variable and function to the corresponding article objects. In this manner, the controlling of C++ objects agrees to OTcl which enables changing the linked variables of C++ from a script of Tcl. Also, it is possible to add variables and functions as C++ linked of OTcl object. Certainly, some of C++ objects that do not need control during the simulation are internally used by other objects that do not require to be connected to OTcl. Figure 3 illustrates the linkage between C++ and OTcl (Wang, 2004).

The user (not necessarily the developer of NS) can be assumed to be standing in left bottom corner, designing and executing the simulations in Tcl by using the simulated objects in the library of OTcl. Then movement from this point to the right top corner which gives more

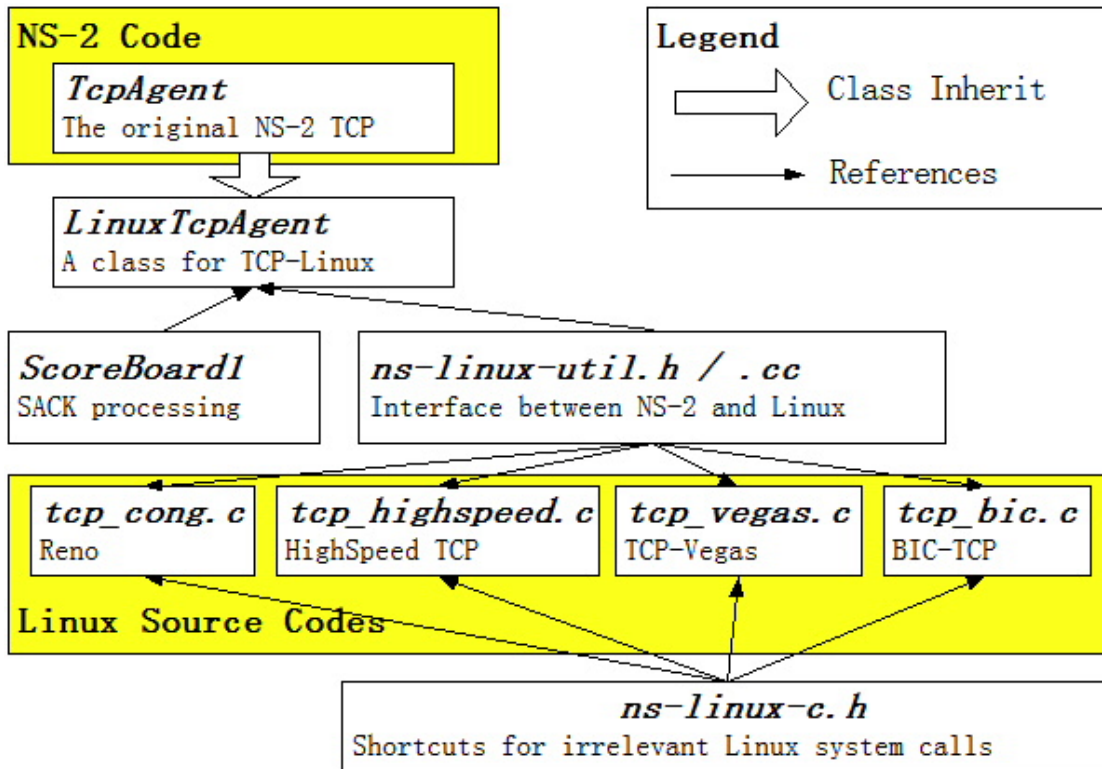


Figure 1. Code structure of TCP Linux in NS-2.

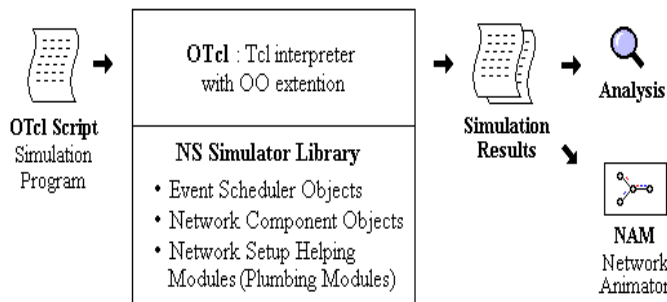


Figure 2. Simplified user's view of NS-2.

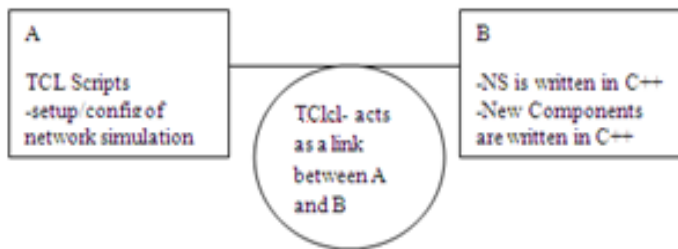


Figure 3. TclCI provides the linkage between C++ and OTcl.

understanding and knowledge of NS-2 as a whole is wanted. The event scheduler and a lot of network

components are executed using C++ language existing as OTcl over a linked article, and is applied using Tcl with classes (tclcl) as a Tcl/C++ interface.

SPECIFICATIONS OF SUMER TCP

The state diagram shown in Figure 4 consists of many phases; however, all these phases represent an integrated and enhanced congestion control algorithm to control the size of congestion window (cwnd) in professional approach with high throughput. As explained, Sumer TCP is an improved Reno with high performance congestion control. Every time when three DUPACK's receive ACK's that means the segment is already lost and the algorithm retransmit this segment again and enter fast recovery mode.

Also, it sets the slow-start threshold (ssthresh) to the half of the current size of cwnd and set cwnd to become $cwnd - cwnd * (2 / (3k + 1))$ where k has already been estimated. On one side, for every DUPACK received, cwnd increases by $k/cwnd$ and when the increasing of cwnd has exceeded the amount of segments in the network pipe there will be transmission of new segment delays. In slow-start phase, the new congestion control uses the duplicated increment with quadratic interpolation to achieve faster increase. The effect of this technique should be used in initial starting up (when the connection

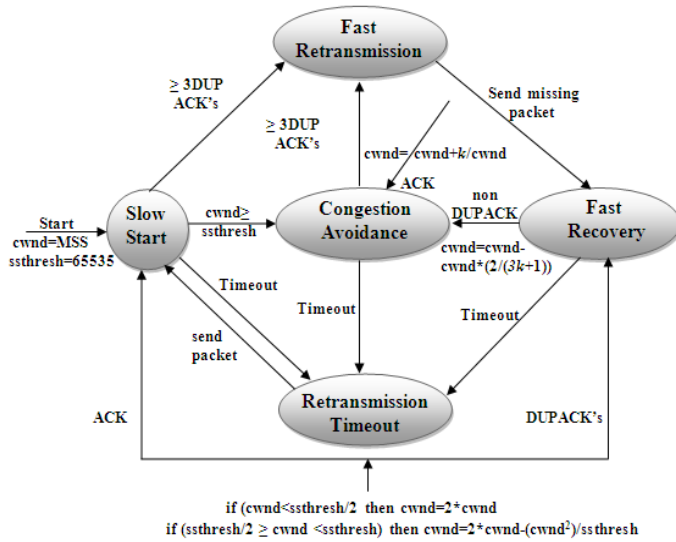


Figure 4. State transition diagram of proposed congestion control mechanism.

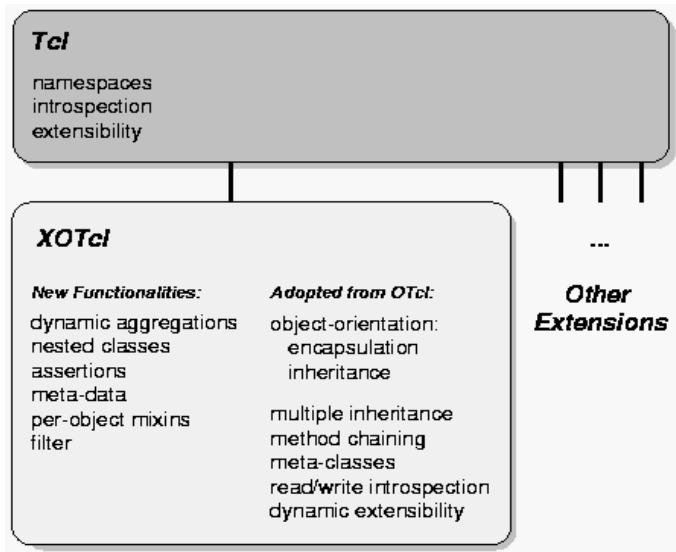


Figure 5. Language extensions of XOTcl.

is established) and after fast recovery mode to obtain faster growth and then delay the congestion avoidance phase as much as possible. In first start up, the cwnd is set to be equal to the MSS (the default value is 1460 Bytes) while the ssthresh is set to be 65535 Bytes, but after the initialization, the cwnd begins estimating according to improved AIMD and the ssthresh according to the network status.

GENERATING SUMER TCP

Many TCP protocol implementations are added to NS-2

such as *Agent/TCP/Reno*, *Agent/TCP/Newreno*, *Agent/TCP/Sack1*, *Agent/TCP/Vegas*, *Agent/TCP/Fack*, and *Agent/TCP* where this one mentions to TCP Tahoe. The main goal here is to create a new TCP agent for Sumer TCP, which is to be identified by NS-2 components and also include the proposed congestion control algorithm. The big challenge in modeling, developing and simulating the networks models and protocols of the researchers, students, and developers are using NS-2 due to the low-level programming language used in this simulator. In this research, the released NS-2.34 is used and this version is installed over Windows XP using Cygwin, where Cygwin provides a Linux-like environment under Windows.

As shown in Figure. 5, the modeling of new module in NS-2 should be constructed with sides, C++ class and OTcl class. The class Tcl Object represents the base class of the most of the other classes in the compiled and interpreted hierarchies.

All objects in the class Tcl Object are generated by the users from inside the interpreter while the equivalent shadow object is generated in the compiled side of the hierarchy and these two objects are narrowly accompanied with each other. The other important class called Tcl Class, represents a pure virtual class in the NS-2 system.

Sumer TCP is built on the same concept of TCP Reno with modification in congestion control, and then the modeling and implementation of Sumer TCP will use the source files of Reno and modify each file separately then use the modified files to create Sumer TCP as a separated TCP agent. For Sumer TCP, it is considered the class becomes SumerTcp Class where it is derived from Tcl Class and is associated with the class SumerTcp Agent. The compiled class hierarchy of SumerTcp Agent is derived from Tcp Agent and that in turn derived from the Agent that in turn roughly derived from Tcl Object.

```
SumerTcpClass is defined as:
static class SumerTcpClass: public TclClass {
public:
SumerTcpClass() : TclClass("Agent/TCP/Sumer") {}
TclObject* create(intargc, const char*const* argv) {
return (new SumerTcpAgent());
}
} class_Sumer;
```

NS-2 will execute the constructor of SumerTcpClass for the static variable class_Sumer when it is first initiated and this setup is both the appropriate approach and interpreted class hierarchy.

In addition, the constructor states the interpreted class clearly as *Agent/TCP/Sumer* and this identifies the interpreted class hierarchy implicitly. The convention in NS-2 is to use the slash character "/" as a separator and for any assumed class A/B/C, the A/B/C class represents

a subclass of A/B where that is a subclass of A, where, A itself is a subclass of TclObject. In SumerTcpClass case, the constructor of TclClass builds three classes, *Agent/TCP/Sumer* subclass of *Agent/TCP* subclass of *Agent* subclass of Tcl Object. The created class is associated with the class SumerTcpAgent and it creates new objects in the associated class. The SumerTcpClass creates method returns TclObjects in the class SumerTcpAgent and if the user identifies new *Agent/TCP/Sumer*, the routine SumerTcpClass is invoked.

MODIFICATIONS IN NS-2

To accept Sumer TCP as a new protocol over the NS-2 platform, many source files are required to create (or modify) to make the RTCP recognizable and ready to merge the new congestion control algorithm. Unfortunately, the procedures to add RTCP in NS-2 files is very sensitive and complex, because there is no professional documentation for these routines and the other risk such as the NS-2 does not include full help in compiling operation (all required modifications done using C++), so when the developers face an error, they should revise all the performed steps. The modified files involved here are based on the version 2.3x of NS; then the proposed TCP termed Sumer is assumed to be experimented over NS-2.3x series. The first modification is applied on ns-compact.tcl file in the location */ns-allinone-2.3x/ns-2.3x/tcl/lib/* as shown below:

By adding:

```
$self map_ns_defaultsns_Sumertcp
```

Then adding:

```
# Agent/TCP/Sumer
TclObject set varMap_(rampdown) rampdown_
TclObject set varMap_(ss-div4) ss-div4_
```

Then adding:

```
setclassMap_(tcp-Sumer)
Agent/TCP/Sumer
  set classMap_(Sumertcp)
Agent/TCP/Sumer
```

Then, the file Makefile.in which locates in: */ns-allinone-2.3x/ns-2.3x/Makefile.in* needs to add a single line in the same groups with the other TCP variants:tcp/tcp-Sumer.o Other single line to the file ns_tcl.cc which locates in: */ns-allinone-2.3x/ns-2.3x/gen/ns_tcl.cc*:
\$self map_ns_defaultsns_Sumertcp\n

Two short lines should be added to FILES in the main NS folder ns-2.3x:

```
tcp/tcp-Sumer.cc
tcp/tcp-Sumer.h
```

In the same file, the next four lines are added as shown below:

```
tcl/test/test-output-tcpVariants/fourdrops_Sumer.gz
tcl/test/test-output-tcpVariants/onedrop_Sumer.gz
tcl/test/test-output-tcpVariants/threedrops_Sumer.gz
tcl/test/test-output-tcpVariants/twodrops_Sumer.gz
```

The last step is to get a copy of the files tcp-Reno.cc and tcp-Reno.h and rename these two files to become tcp-Sumer.cc and tcp-Sumer.h respectively. The file tcp-Sumer.h characterizes the header file where will be defined the routing agent and all necessary timers which performs the functionality of the Sumer TCP protocol. To validate the generating of Sumer TCP over NS-2, we experimented the new agent by drawing the congestion window of packet transmission in simple network topology. The first test was based on plotting the congestion window without congestion event as shown in Figure 6 where we used 60 packets as a window size and 20 s as simulation period.

In this figure we can note the typical congestion window of Sumer TCP and we can observe the new behavior of Sumer TCP without congestion event in the simulation scenario. The other test of Sumer TCP proceeded with simple congestion event by adding packet loss to the link and proposed topology by reducing the bandwidth of the network bottleneck as shown in Figure 7. The last test proceeded to validate the congestion control mechanism behavior when the network suffers from congestion events by adding some cross links and increasing the packet loss. In this test the window size was 20 packets and the simulation period was 10 s.

CONCLUSIONS

In this paper, a new TCP called Sumer was created and is based and carried out on the general concepts and features of TCP Reno. The improved TCP used new congestion control mechanism in enhancing the window behavior in slow-start and congestion avoidance phases. This paper had also involved in creating the agent of Sumer in NS-2 modeler and identifying and configuring Sumer TCP over the NS-2 platform. The new TCP agent was generated by adding many subroutines, algorithms, and functions to make the new agent readable by the NS-2 compiler. Furthermore, the TCP modeling is required to add many source files and headers to build the structure of the new TCP where the new files and headers are programmed using C++ language. The pseudo code of all files, routines, and subroutines are illustrated in this article.

FUTURE WORK

Further researches on this article will emphasize modification

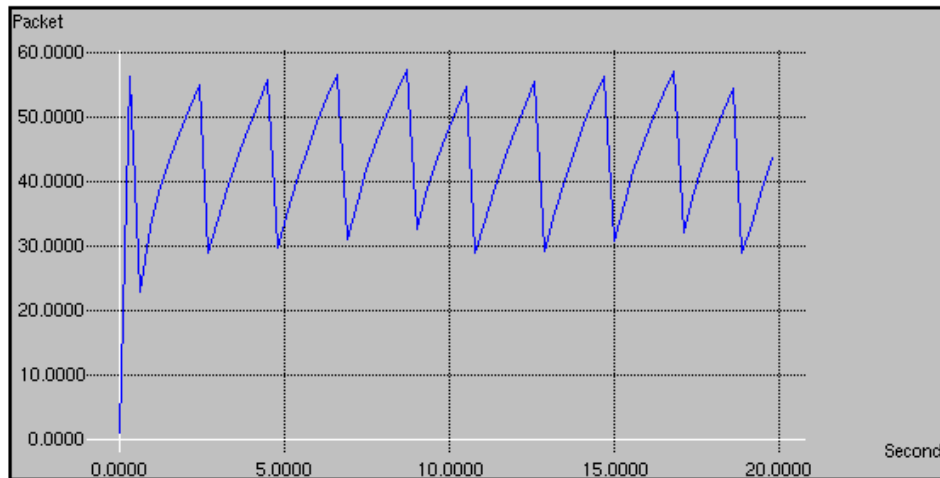


Figure 6. Congestion window of Sumer TCP without network congestion.

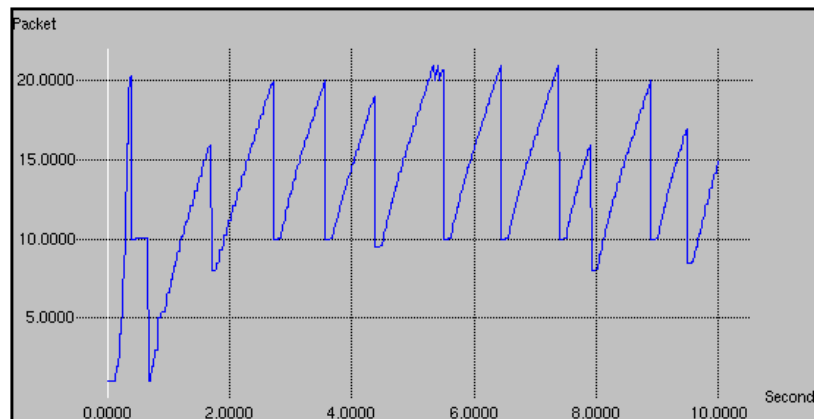


Figure 7. Congestion window of Sumer TCP with network congestion.

of the congestion control mechanism of Sumer TCP to give the new agent some private and useful features.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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