A NOVEL ROUTING ALGORITHM FOR VIDEO-ON-DEMAND ON MOBILE DEVICES

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Abstract

Bandwidth is one of the characteristics that is used to measure network performance. In this paper, we present A Novel Routing Algorithm (ANORA) for Video-On-Demand on Mobile Devices that are streaming video contents from a video server. The algorithm can adapt to different number of mobile devices with different level of mobility and different location. Routing decisions are based on the availability of the packet(s) within a given geographical location. The video server identifies the availability of the packets it has earlier sent to a particular client and requests the packet(s) to be forwarded to the requesting client. Real live video programme was streamed using VLC media player and the collected packets size and packet inter-arrival times were used in all the simulations. Different simulations were conducted using OPNET Modeler. After conducting series of simulation tests, the algorithm showed low server and network load, low delay, high adaptability and robustness.

Keywords: IPTV; video-streaming; VoD; MANET; bandwidth; routing; OPNET; simulation; delay

1. INTRODUCTION

Television and video on demand (VoD) services have been transformed from using conventional radio signals and satellite technology to the use of Internet to deliver video contents to the end users. The definition of Internet Protocol Television (IPTV) as approved by International Telecommunication Union Focus Group on IPTV (ITU-T FG IPTV) “is a multimedia services such as television/ video/ audio/ text/ graphics/ data delivered over Internet Protocol (IP) based networks, managed to provide the required level of quality of service and experience, security, interactivity and reliability" (Krbic et al. 2010). IPTV is not just about transmitting digital television services over the Internet technology; it is about reinventing television to better achieve the required goals and creating a video-centric next-generation Internet accessible on any device, such as a mobile phone, tablets, computer, or HDTV, at any time and place the consumer chooses(Retnasothie et al. 2006). This makes demand for IPTV services in wireless networks higher and is expected to continue increasing over time (Š Krbic et al. 2010).

The main services offered by IPTV can simply be categorized into three main services:

Live television, time shifted programme and Video on Demand (VoD). Currently, these services offered by IPTV uses two main schemes; Multicast and Unicast.

Multicast- This scheme is used for delivering live video and time shifted programmes. Multicasting is the networking technique of distributing the same packet concurrently to a group of consumers. Internet Protocol (IP) Multicasting is a proficient bandwidth-conserving mechanism where a source node simultaneously transmits the same content to a group of destination nodes called multicasting group (Hu et al. 2012).

Unicast- Unicast is used for video on demand and other applications services. Internet Protocol (IP) Unicast is a mechanism where separate contents from the source server are sent to each destination host. Unicast streaming establishes one to one connection between a server and client(Hu et al. 2012).

Bandwidth is one of the characteristics that is used to measure network performance. However, the term bandwidth in a network can be used in two different contexts with two different measure values, namely bandwidth in Hertz and bandwidth in bits per second. Bandwidth in Hertz is a range of frequencies contained in a composite signal or a range of frequencies a channel can pass. While bandwidth in bits per second refers to a number of bits per second that a channel, a link or a network can transmits.

The channel capacity is given by an expression often known as “Shannon’s formula”:

$$\mathbf{C = W \log2 (1 + P/N)\ bits/second} \quad (1)$$

The essential elements of the formula (1) are:
W - Proportionality to bandwidth
S - Signal power
P - Noise power

The “Shannon’s formula” (1) gives an expression for how many bits of information can be transmitted per second over a channel with a bandwidth of ***W*** in Hertz (Hz), when the average signal power is limited to ***P*** watt, and the signal is exposed to an additive, white (uncorrelated) noise of power N with Gaussian probability distribution (Shannon 2001).

According to "Nyquist formula" (2), for a given bandwidth, the highest theoretical bit rate is twice than the bandwidth (Breu et al. 2008). Thus;

$$\mathbf{fb = 2B} \qquad (2)$$

Where:
fb is the bit rate in bps
B is the bandwidth in Hertz

To provide IPTV services with the required guarantee of quality of service (QoS) and quality of experience (QoE) to the end users, the required minimum bandwidth by server to serve all the requests received from the clients must be met. Hence, there is a need for an algorithm that the server can take advantage of Mobile ad hoc Networks (MANET) features and client resources in serving other requests.

In this study, we developed and simulated a new algorithm called A Novel Routing Algorithm (ANORA) for Video-On-Demand on Mobile Devices using OPNET Modeler. The proposed routing algorithm adopts and expands on the features of reactive routing protocol of MANET in route discovery and packets forwarding to the intended destination. The results show that the algorithm provides unlimited virtual bandwidth and reduces overload for the source node without affecting the general quality of service.

This paper is organised in six sections. Section I provides the introduction, section II provides the background and related work, section III provides the overview on the use of OPNET, section IV is the description of the proposed algorithm and its implementation in OPNET, section V details the analysis of results of the simulation, and section VI provides the conclusion.

2. Related Work

A Mobile Ad hoc Network (MANET) is an autonomous system of mobile devices that are connected via wireless links without prior planning or needs of any existing network infrastructure. Mobile devices are communicating to each other not only as source or destination but also as routers in wireless network. Routing and packet forwarding in MANETs are among the most active research topics in the area of wireless communication as can be seen in (Srikanth 2011)(Qin 2005)(Acharya et al. 2002)(Silvestre & Vazao 2010).

Ad hoc routing scheme for MANET is categorized into proactive, reactive and hybrid approaches (Kum et al. 2012)(Kuppusamy 2011). Proactive routing protocols such as Dynamic Destination Sequenced Distance Vector routing (DSDV)(Prateek 2013) and Optimal Link-State Routing (OLSR)(Jacquet et al. n.d.) maintains individual nodes' routing table/information about the available paths in the network even if the paths are not currently in use (Kuppusamy 2011)(Qin 2005). Each node maintains consistent and up-to-date routing information by sending a control message (HELLO messages) between nodes periodically for the nodes to update their routing tables.

Reactive routing protocols include Dynamic Source Routing (DSR) (Johnson & Maltz 1996) and Ad hoc On-Demand Vector routing (AODV) (Perkins & Royer 1999) which maintains only the routes that are currently in use (Qin 2005). In reactive or on demand routing protocol the route discovery mechanism is started by the source in finding the route to the destination and it remain valid until the destination is unreachable or until the route is no longer needed (Kuppusamy 2011). Unlike the proactive/table driven protocols, all nodes needs not to maintain and up-date routing information.

Hybrid routing protocols such as Zonal Routing Protocol (ZRP) (Yélémou 2012) and Temporally-Ordered Routing Algorithm (TORA) (Lim & Datta 2012) combines the advantages of both proactive and reactive routing protocols. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding.

This paper proposes algorithm that uses AODV routing protocol approaches where the source node finds and maintains the route to the destination. Maintaining information about the available routing path by source node can be greatly regarded as useful in the designing the new algorithm. The amount of bandwidth consumption when keeping track of routing information is done by the source nodes is far less than the amount of bandwidth consumption when routing information updates are sent to each and every node in the network. The paper also outlines the early work in the research that focuses on the different ways of achieving effective utilization of bandwidth in IPTV. Some of the studies carried out in this area of research include:

A unicast routing algorithm called Simple Wide-deploy Algorithm for Ad hoc Networks (SWAN) was proposed by (Silvestre & Vazao 2010). As described in their work, the main contributions of the new algorithm are; low overhead, high delivery ratio, absence of a route repair process, self-adaptive, sending messages using an optimal route and its capability of sending messages in a network with voids or fragmented using angle correction and the proxy state. However, this proposed algorithm only focuses on optimizing route discovery within the network nodes.

Also a Look-Ahead Unicast Routing (LAUR) protocol was proposed by (Qin 2005). LAUR protocol is based on source node for route discovery. As explained in their paper, LAUR does not flood the network with control packets, instead, the source selects one of it is neighbors to send out a route request packet by using the prior information the source acquires from its neighbours to determine an appropriate route that could lead to the destination. Even though, the algorithm is based on the source node, but it is main aim is to enhance the source node route discovery that lead to the destination, given less or no concern about the source overload and bandwidth.

Another protocol called Unified Unicast and Multicast Label (UNCLE) was proposed by (Jia & Wang 2012). The proposed protocol uses cross layer scheme for single protocol stack for both unicast and multicast in it is forwarding method. The scheme was designed based on simple modulo approach which reduces the protocol overhead when compared with the traditional stateless unicast Dynamic Source Routing (DSR) and Differential Destination Multicast (DDM) schemes as the explained in their paper. However, this scheme does not take source node capacity into account, and it is designed for using single protocol stack for content forwarding.

An Adaptive Hybrid Transmission (ART) schemes for on-demand mobile IPTV service over wireless mesh networks was also proposed by (Augustine 2012). The proposed algorithm utilizes hybrid mechanism that combines Multi-channel multicasting and unicast scheme to enhance service over service blocking probability and reduce the bandwidth consumption of the wireless system. However, the algorithm emphasis on enhancing service blocking and reduction of bandwidth on the wireless network not the source node.

All the proposed algorithms, protocols and schemes stated above gave emphasis on either optimizing route discovery, reduce protocol overhead, reduction in network overload and bandwidth consumption on client site. However, as much as the quality of service is enhanced at the clients' end, if the server is incapacitated to serve those clients' requests, then the purpose has been defeated. Thus, the server should be given the highest consideration in the improvement of quality of service especially during high demand.

3. Overview Of OPNET Modeler

OPNET Modeler is one of the leading commercial products that provide computer networks modelling and simulation (Hnatyshin et al. 2010). It is a discrete event simulator that is widely used by researchers, engineers, university students, and the United State department of defense. OPNET Modeler has a user-friendly graphic user interface (GUI), supported by object-oriented and hierarchical modelling, debugging, and analysis. It supports hybrid simulation, analytical simulation, 32-bits and 64-bits fully parallel simulation and providing many other features (Lu & Yang 2012). OPNET Modeler has grid-computing support for distributed simulation and Its System-in-the-Loop interface allows simulation with external computer systems which provides real-world data into the simulation environment. The interface for integrating with external objects files, libraries, and its in-build wider collection of numerous type of protocols and hundreds of different vendor computer and communication devices, model with source code as well as inclusion of development environment to enable users to model different types of network devices and protocols of their choice. This accelerated the research and development process for designing and analysing of different communication networks, devices, protocols, and applications (Lu & Yang 2012). Figure 1 shows the hierarchical structure of OPNET from a network structure view to node model to process model and to the programming code.

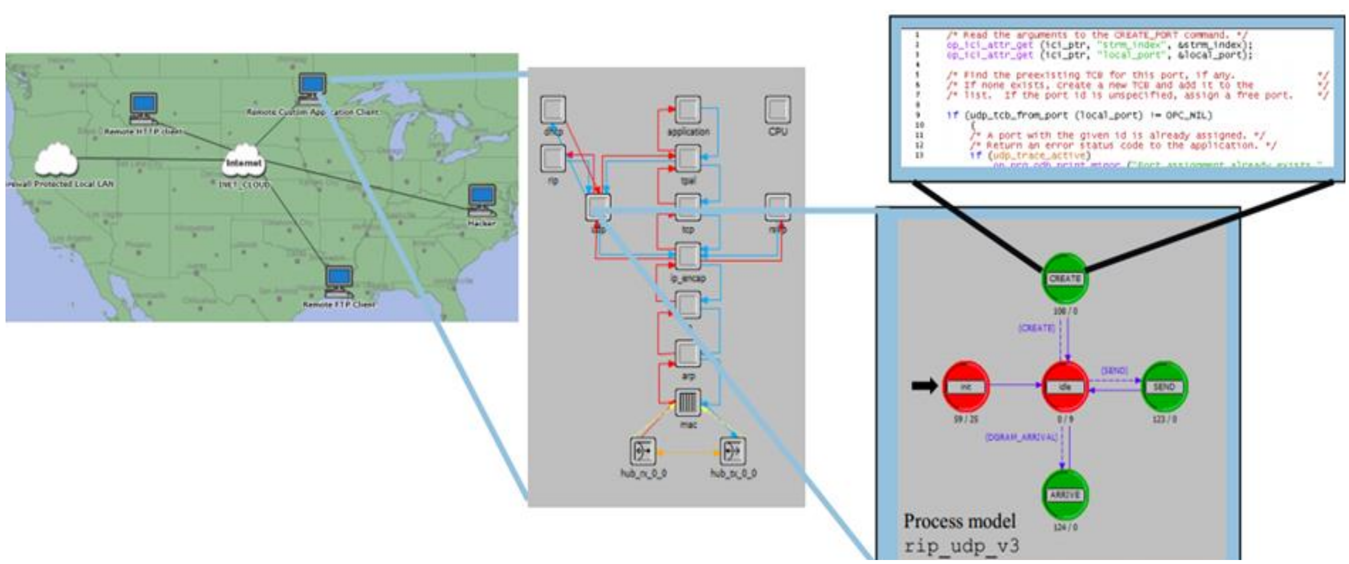

Fig. 1. The Three Tiered OPNET Hierarchy(OPNET Technologies 2012).

OPNET Modeler uses the combination of C/C++ programming languages and state transition diagrams in the designing and implementation of simulation models. Whilst developing a new model and simulation study using standard models is a straight-forward task, however, modifying existing models can be difficult and often frustrating task. Identifying process models, external files or part of the code that are responsible for simulating a particular system's performance on task could be challenging despite extensive documentation. Thus, modifying OPNET process model could become time consuming and highly challenging.

This paper focuses on modifying existing video streaming server manager process in OPNET called gna_video_streaming_server_mgr.pr to incorporate the proposed algorithm. This server process manager is responsible for sending video streaming packets to the video streaming clients. The server node model calls the function of gna_video_streaming_server_mgr.pr to serve the video streaming requests. Figure 2 shows the server node model whilst Figure 3 demonstrates the video streaming server manager process.

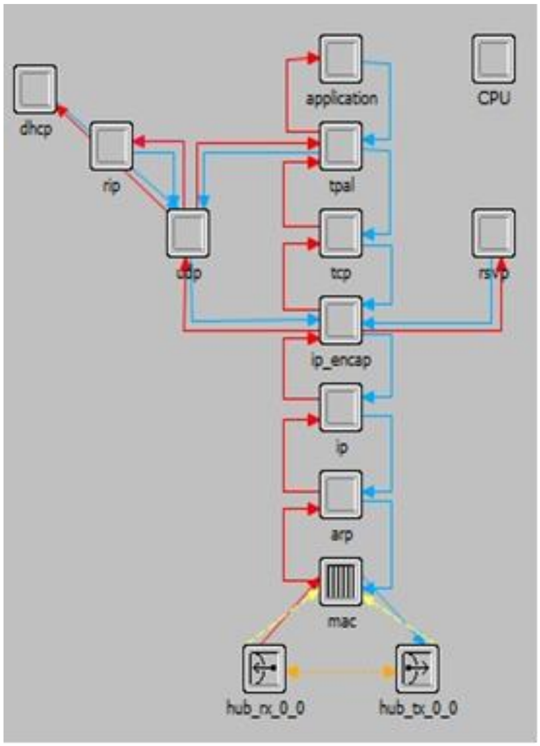

Fig. 2. Server node model

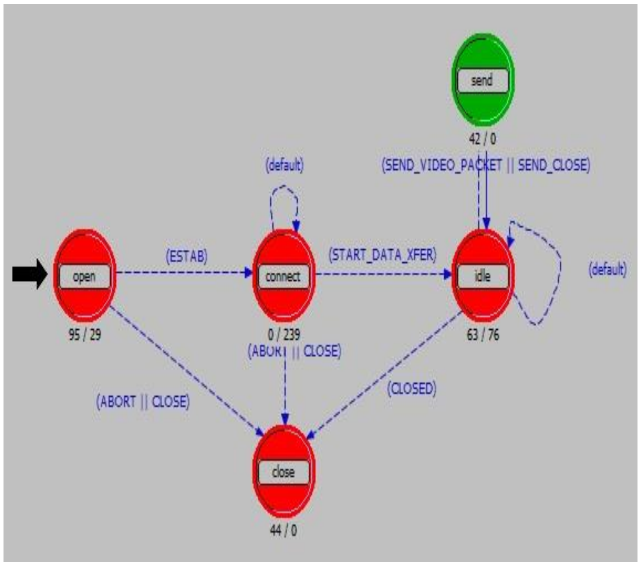

Fig. 3. Video streaming server manager process

4. Description And Implementation Of ANORA In OPNET Modeler 17.5

The main characteristic of MANETs is the absence of fixed infrastructure, this characteristic provides some certain advantages in its deployment, as routing task is distributed over the network devices, as such there is no investment cost on the infrastructure and the total dependency on the source node have been overcome.

ANORA is a unicast routing algorithm that effectively utilises network devices' bandwidth and resources in sending video streaming packets to a designated destination. Rather than depending always on one source node to serve each request received from client nodes, some of the requests are redirected to other client nodes within the network and location of the requesting client, which have already requested and received the packet(s) to forward it to the requesting node. Each client in the network belongs to a group and the grouping is done based on the common clients' watching behavior and location. Stipulated time is set within which the packet is believed to be available in the client's storage after which the source node deletes the information about that packet in its routing table. All the nodes in the network send routing information to the source node with the updates of their availability and location.

To predict the success of the proposed algorithm, it is imperative to measure the probability of successfully obtaining and forwarding available requested packet(s) from one or more IPTV client to the other. Based on consecutive steps described below for searching and forwarding packet(s) process, a binomial distribution theory (3) and (4), was used to evaluate the probability of success. We have $\boldsymbol{n}$ as total number of clients on the network and $\boldsymbol{k}$ as the number of clients that have the packet(s). Assume that the probability that the packet is found and is successfully transmitted

p = 0.3 and ***q = (1 – p).***

Thus:

$$(\boldsymbol{p}+\boldsymbol{q})^{\boldsymbol{n}} = \sum_{\boldsymbol{k}=\boldsymbol{0}}^{\boldsymbol{n}} \binom{\boldsymbol{n}}{\boldsymbol{k}} \boldsymbol{p}^{\boldsymbol{k}} \boldsymbol{q}^{\boldsymbol{n}-\boldsymbol{k}} \quad \textbf{(3)}$$

$$\binom{\boldsymbol{n}}{\boldsymbol{k}} = \frac{\boldsymbol{n}!}{\boldsymbol{k}!(\boldsymbol{n}-\boldsymbol{k})!} \quad \textbf{(4)}$$

Where: $\boldsymbol{p}$ is the probability of success

$\boldsymbol{q}$ is the probability of failure

In this research study, 20 nodes and 100 nodes were used in two separate projects for investigational purposes. In the first project, $\boldsymbol{n}$ **= 20** and $\boldsymbol{k}$ starts from 0 to $\boldsymbol{n}$, the probability $\boldsymbol{p}$ that the packet(s) is found in one or more client is calculated using the binomial distribution theory above and the results is = **0.9997.** In the second project, $\boldsymbol{n}$ **= 100** the probability $\boldsymbol{p}$ that that packet(s) is found on one or more clients is calculated to be **1.000**. Therefore, this shows that the probability that a packet(s) is found in one or more clients and transmitted successfully is very high in both projects, thus the server workload will be reduced by requesting other clients to forward some requested packets on it is behalf. This results tally with the simulation results where the saver load is reduced in both projects considerably.

In the cause of this research, 2 KM mobility radius in each group and five minutes were used. The algorithm works in the following steps as illustrated in figure 4.

Step 1: When a video streaming request is received by the server node from a client node, the source node first checks its routing information to identify any node(s) that already received the same requested packet(s) within the node group

Request of $X_{i...n}$ Packet(s)
For each element in the array Group j[ ]
Check if
X_i is available
Return TRUE

Step 2: If the client node that has the packet(s) is identified then the server check the time the packet was sent and the number of forward request (FREQ) messages. If the time is within the set time and there is no FREQ message to that client, then the server node sends a FREQ message to that client with the destination address in the message header for the packet to be forwarded to the requesting node, update its routing table and end.

Then check if time <= 5 and FREQ = 0
Return TRUE
Send FREQ to the client
Update
End

Step 3: If no client is found within the group of the requesting client or the set time elapsed or there is already a FREQ message sent to that client.

Else
Return FALSE

Step 4: The server checks the same packet in the other groups

For each element in arrays $G_{j+1....n}$[ ]

Step 5: If the client node that has the packet(s) is identified in the other groups, then the server checks the time the packet was sent and number of FREQ messages.

If X_i is available
Return TRUE
Then check if time <= 5 and FREQ = 0

Step 6: if the time is within the set time and there is no FREQ message sent to that client, then the server node sends a FREQ message to that client with the destination address in the message header for the packet to be forwarded to the requesting node, update its routing table and end.

Return TRUE
Send FREQ message to the client
Update
End

Step 7: If no client node is found that has the packet or the stipulated time elapsed or there is a FREQ message sent to that client, then the source node have to serve the request directly by forwarding the requested packet(s) to the requesting node, updates its routing information and ends.

Else
Return FALSE
Send X_i
Update
End

When many clients' requests were received by the source node at the same time, the requests should better be served using multicast scheme. The proposed algorithm is limited to the use of unicast scheme. Incorporated multicast may be considered in the next phase of the research.

In all the steps described above, route reply messages (RREP) propagated back to the source node when the route path has been discovered. Also route error message (RERR) is propagated back to the source node to be notified on any broken link.

The ANORA algorithm was incorporated in the video_streaming_server_mgr process. This server process is responsible of sending video streaming packets to the video streaming clients. The server process manager is responsible of serving all requests of all the application services supported by the server such as e-mail, web browsing, printer, data base, file transfer etc. Hence, clsvr_mgr process calls the services of video_streaming_server_mgr process whenever a video streaming request was received. The Algorithm's code was written, compiled and saved in a different OPNET video streaming server.

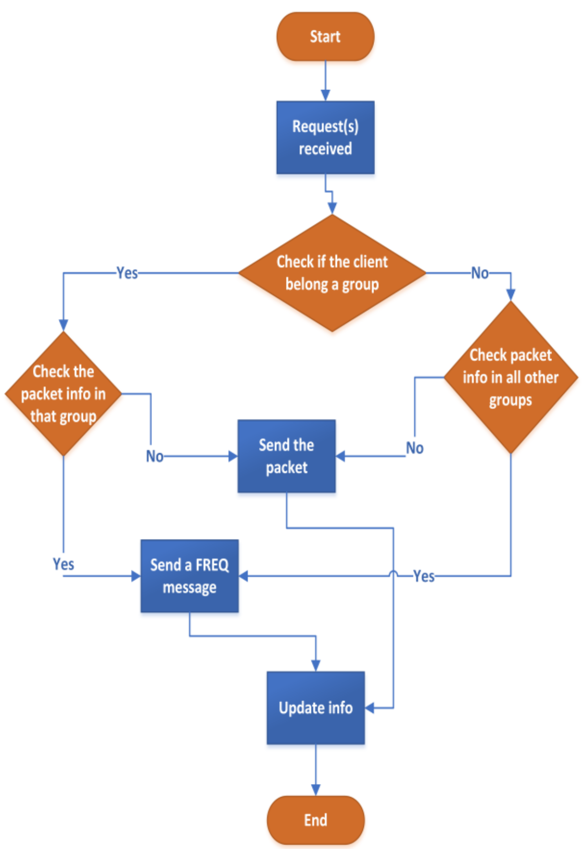

Fig. 4. The proposed algorithm (ANORA) flowchart

With the support of real-world data in to OPNET modeler which include video streaming. In other words a video streaming traffic can be captured by a given video streaming software such as VLC into a file, and then use the file in OPNET Modeler to simulate the same traffic in a scenario (OPNET Technologies 2014). In this research a live video programme (winter Olympics 2014) was streamed using BBC iplayer (BBC 2014) and the video captured file was stored in the OPNET primary directory (that is, the first directory listed in OPNET) in the model directories and used to simulate all the scenarios.

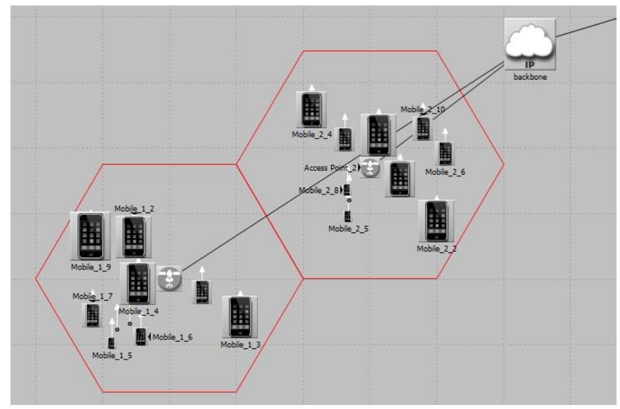

Fig. 5. Network setup for 20 mobile phones

TABLE 1: SUMMERY OF NODE CONFIGURATION

Configuration parameter	Value
Wireless technology	IEEE 802.11n
Mobility	Random waypoint
Packet Reception Power Threshold	-95dB
Data rate	6.5 Mbps (base) / 60 Mbps (max)
Start of data transmission	normal (100, 5) seconds
End of data transmission	End of simulation
Duration of Simulation	3600 seconds (1hr)
Packet inter-arrival time	Based on the captured data
Packet size exponential	Based on the captured data

The work was designed and modeled in two different projects with two scenarios in each project. The first project was designed with two groups of ten mobile phones each, as shown in figure 5. The second project was model with ten groups of ten mobile phones each, as shown in figure 6. These scenarios represent the typical IPTV clients streaming video contents from a video streaming server over the Internet. All the four different scenarios were simulated for one hour each, to evaluate the performance of the algorithm. The projects parameters were set in all the four scenarios as shown in table 1. The following are the description of scenarios used in the project.

Scenario 1: two groups of ten mobile phones each, streaming video packets from video streaming server process model with ANORA over the Internet.

Scenario 2: two groups of ten mobile phones each, streaming video packets from normal video streaming server process model over the Internet.

Scenario 3: ten groups of ten mobile phones each, streaming video packets from video streaming server process model with ANORA over the Internet

Scenario 4: ten groups of ten mobile phones each, streaming video packets from normal video streaming server process model over the Internet.

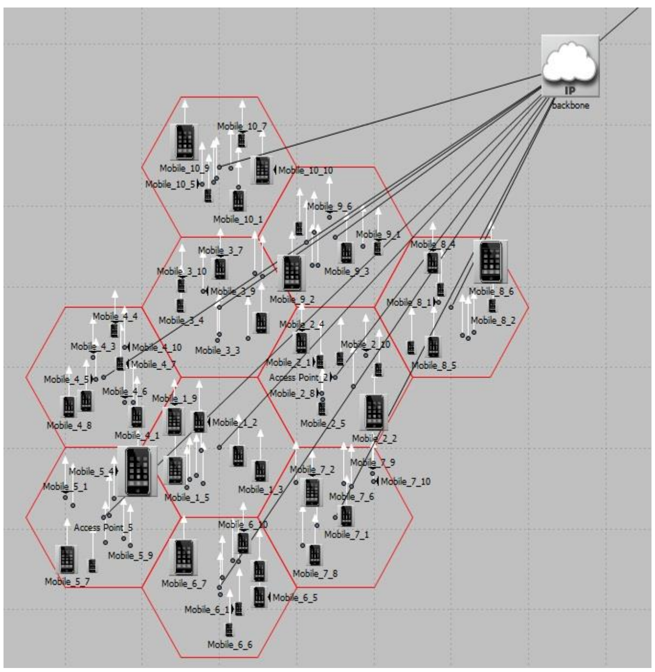

Fig. 6. Network setup for 100 mobile phones

5. RESULT ANALYSIS

The average wireless LAN delay, average delay variation (Jitter), average video streaming packets sent by the source node and average server load were compared and analysed in both projects. Wireless LAN delay is the end-to-end delay for all the packets received by the wireless LAN Medium Access Control (MAC) layers of all wireless LAN nodes in the network and forwarded it to higher layer. This delay includes the medium access delay at the source MAC (OPNET Technologies 2014). The 802.11 standard specifies a common MAC Layer that provides variety of functions that support the operation of 802.11-based wireless LANs. The main responsibility of MAC Layer is to manage and maintains communication between 802.11 stations such as radio network cards and access points by coordinating access to share radio channel and utilizing protocol that enhance communications over wireless medium.

Figure 7 shows the average delays for the first project (i.e. two groups of ten mobile phones each). Scenario 1 is the server process manager that the proposed algorithm (ANORA) is incorporated and Scenario 2 is the normal server process manager. Scenario 1 (with ANORA) has the lowest average wireless LAN delay compared to Scenario 2. Figure 8 shows the average delays for the second project (ten groups of ten mobile phones each). Scenario 3 is the server process manager where the proposed algorithm (ANORA) is incorporated and Scenario 4 is the normal server process manager. In this project also the results shows that the proposed algorithm produced low wireless LAN delay.

Server load represents the total load in bits/sec at the source node (OPNET Technologies 2014). Figure 9 shows the average server load for the first project (two groups of ten mobile phones each). In Scenario 1 the proposed algorithm is incorporated in the server process manager whilst Scenario 2 is the normal server process manger. As anticipated, Scenario 1 has the lowest server load compared to scenario 2. Figure 10 displays the average server loads for the second project (ten groups of ten mobile phones each). Scenario 3 is where the proposed algorithm is incorporated in server process whist Scenario 4 is the normal server process. The results show that Scenario 3 has the lowest server load compared to Scenario 4. Hence, the proposed algorithm (ANORA) reduces reasonable percentage of server load.

Figure 11 and 12 show the average number of packets sent by the server. The first project (one group of ten mobile phones), Scenario 1 (with ANORA) shows less number of packet sent by the server compared to Scenario 2 (Normal IPTV). Also in the second project, Scenario 3 (with ANORA) shows less numbers of packets sent by the server compared to Scenario 4 (Normal IPTV). Thus this also shows that the proposed algorithm reduces the amount of workload at the server node.

The average delay variation (jitter) results for both projects were displayed in figure 13 and figure 14. The results show that the sever process manager with the proposed algorithm (ANORA) produced higher amount of jitter than the normal server process manager. Thus, jitter is sensitive to real time applications, this may results in packets drops on live video transmission, which may leads to poor quality of service. However, the algorithm could be more effective on VoD video streaming programme where buffering mechanism is used.

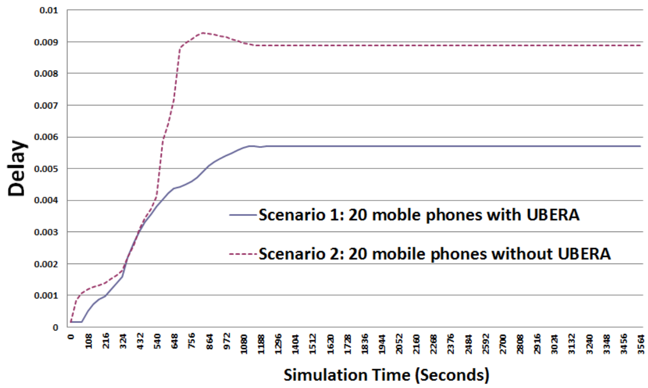

Fig. 7.   Wireless LAN Delay

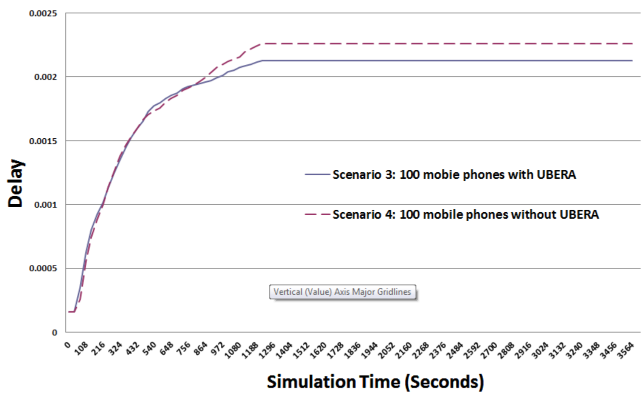

Fig. 8.   Wireless LAN Delay

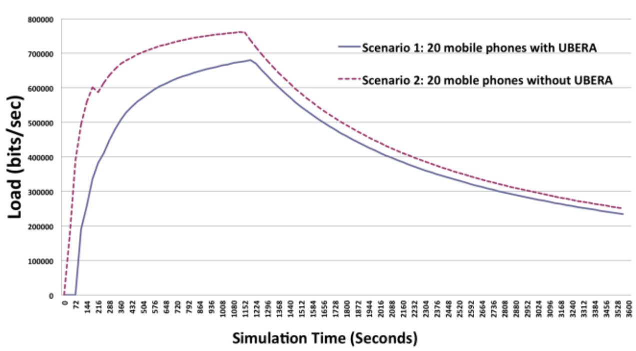

Fig. 9.   Server load

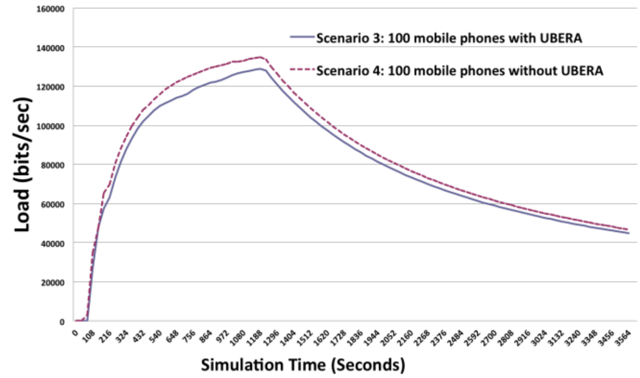

Fig. 10. Server load

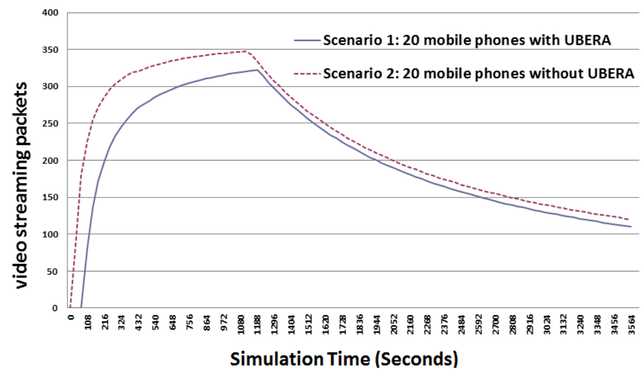

Fig. 11. Average Video Streaming Packets Sent

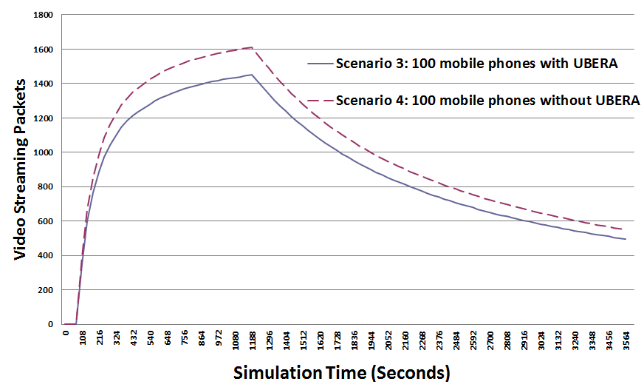

Fig. 12. Average Video Streaming Packets Sent

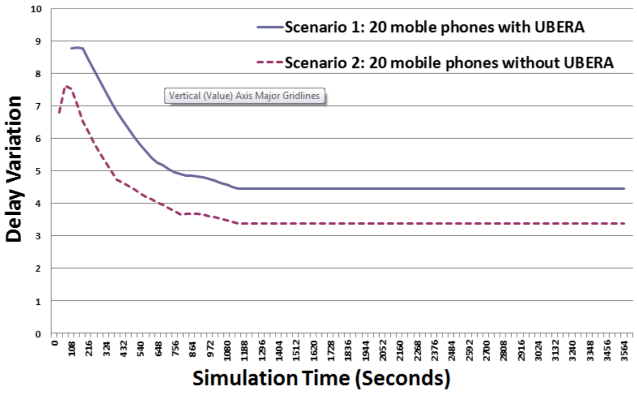

Fig. 13. Jitter

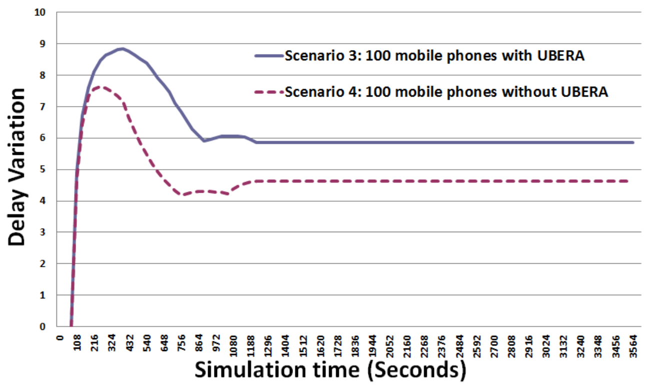

Fig. 14. Jitter

6. CONCLUSION

In this paper A Novel Routing Algorithm (ANORA) for Video-On-Demand on Mobile Devices that are streaming video contents was presented. Challenges facing delivery of video contents over the Internet, specifically bandwidth were presented. Analytical and simulation approach were conducted. Binomial probability distributions were used to determine the successful retrieval and transmissions of the requested packets. Simulations of a typical IPTV network where client nodes are streaming video contents from a video server over the Internet were created and run. The proposed algorithm was incorporated into the video streaming server in OPNET Modeler and the network was simulated to evaluate its effectiveness. The results analysed show that ANORA perform as predicted saving considerable amount of network load and server bandwidth as well as enhancing the quality of services by reducing the amount of network delay. However, the proposed algorithm shows higher amount of jitter, thus it may not be effective on live video transmission. The proposed Algorithm will be more effective on VoD and video streaming programme where buffering mechanism is implemented.

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