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Network Constraints Reduction by TORA in MANET

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Abstract: Mobile Ad hoc Networks (MANETs) are characterized by bandwidth constrained links, multiple hops and dynamic topologies. Routing should provide quality of service in the mobile adhoc networks is a highly challenging task. In this study, we discussed the unicast routing in MANETs with enhancements to the Temporally Ordered Routing Algorithm (TORA). Temporally Ordered Routing Algorithm (TORA) is a highly scalable routing protocol for MANETs. TORA is dependent on the services provided by the internet encapsulation protocol to effectively carry out with its three main functions; route creation, route maintenance and route erasing. Route discovery in TORA is done in a cooperative manner with intermediate nodes contributing to the route generation from one node to another. Precision in route build-up demands that all network nodes portray persistent benevolent behaviour. This is however, not always possible to achieve and so a number of malicious nodes participate in the route discovery process only to sabotage the network by violating the protocol. This study will give the novel mechanism for establishing trust in ad-hoc networks that execute the Temporally Ordered Routing Algorithm (TORA) protocol. The main objective is to limit control message propagation in the highly dynamic mobile computing environment. Each node has to explicitly initiate a query when it needs to send data to a particular destination.

Key words: Network constraints reduction, temporally ordered routing algorithm, mobile ad hoc networks, mechanism, dynamic, persistent

INTRODUCTION

The proliferation of mobile computing and communication devices (e.g., cell phones, laptops, handheld digital devices, personal digital assistants) is driving a revolutionary change in our information society (Ilyas, 2002). The studies and developments in wireless networking have primarily been driven by success of the dominant cellular architecture model. Thus, although, significant progress has been achieved in the thorough understanding of wireless networking characteristics through the study of cellular systems, many of the developments are still not directly applicable to satisfy the needs of the wireless systems that require network architectures which may not follow the cellular paradigm. Such networks, sometimes referred to as wireless ad-hoc, or peer-to-peer or multi-hop networks, consists entirely of wireless and often mobile nodes that may communicate either directly or via. multiple hop paths that require the support of intermediate nodes to achieve connectivity. Wireless Adhoc networks which have node mobility are called Mobile Ad hoc Networks (MANETs). A collection of wireless mobile nodes can vigorously establish the network in the absence of fixed groundwork (Mahajan and Chopra, 2013). Because of these features, routing is a serious issue and ancompetent routing protocol needs to be chosen to make the MANET trustworthy (Hinds *et al*., 2013). Wireless ad-hoc networks are autonomous systems of fixed or mobile wireless nodes with routing capabilities, that may operate in a stand-alone fashion or as part of larger heterogeneous network. Although, their development was initially driven by the needs of military networks they are expected to enhance commercial systems as well especially with the evolving use of personal communication services systems. For instance, they can be deployed in collaborative network scenarios where individual users need to share or exchange information without depending on a local network of access points. Routes between two hosts in MANET may consist of hops through other hosts in the network (Xia *et al*., 2009). So, ad hoc wireless networks consist of a collection of geographically distributed nodes that communicate over a wireless medium but have no fixed infrastructure available and have no predetermined network topology (Ilyas, 2003; Wu and Dai, 2003). The networks are malleable and suit numerous conditions and applications, thereby allowing the establishment of temporary communication sans pre-installed infrastructure (Mahajan and Chopra, 2013). There are many potential applications such as home networks of heterogenous devices, industrial robotics and others. Ad hoc networking is equivalent to peer-to-peer

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networking and nodes are mobile. That means there is no need of any access point to connect to any other node in the network. Shrivastava *et al.* (2011) mobile nodes can communicate directly via wireless link if they are within each other's radio range and if not, they rely on other neighboring nodes which act as routers to relay packets (Bhatia and Sood, 2014).

The wireless architectures exhibit several noticeable characteristics that make them quite different from the existing cellular systems and wireless LANs. In wireless ad-hoc networks the existence of a link between any two nodes depends on a multitude of parameters such as transmission power level, distance from the receiver, interference from other transmitters, propagation effects (e.g., multi-path, shadowing, etc.) type of antennas used (e.g., omnidirectional or highly-directional) etc. Nodes may move frequently and in an arbitrary fashion and/or may select to turn their power "OFF" at any time in order to conserve their battery reserves. Thus, the ad-hoc network topology is not stable, may change randomly and unpredictably and consists of varying capacity links. Although, in some simulations, there may or may not be certain nodes in the role of local coordinators (similar to that of a base station), protocols designed to perform network control and signaling functions must operate in a distributed fashion. The overhead associated with collecting and maintaining global network state information prohibits the use of schemes that control operation through a central coordinator node. The distributed algorithms that do not depend on the status of a single node are not directly affected by individual node/link failures that occur often in such environments. Routing protocols define a set of rules which governs the journey of message packets from source to destination in a network (Ilyas, 2002). Thus, the maturity of wireless transmissions and popularity of portable computing devices have made the dream (Ilyas, 2003) of "communication any time and any where" possible TORA uses three kinds of messages: The QRY message for creating a route, The UPD message for both creating and maintaining routes, The CLR message for erasing a route.

We can characterized the life cycle of mobile ad hoc network into first, second and third generation. Present ad hoc network is considered the third generation (Taneja and Patel, 2007). The first generation of ad hoc network can be traced back to 1970's. In 1970's, these are called Packet Radio Network (PRNET) (Bakht, 2004). The Defence Advanced Research Project Agency (DARPA) initiated research of using packet-switched radio communication to provide reliable communication between computers and urbanized PRNET. Basically PRNET uses the combination of Areal Location of Hazardous Atmospheres (ALOHA) and Carrier Sense Multiple Access (CSMA) for multiple access and distance vector routing (Ramanathan and Redi, 2002; Taneja and Patel, 2007).

MATERIALS AND METHODS

Applications: Besides the legacy applications that move from traditional infra structured environment into the ad hoc context, a great deal of new services can and will be generated for the new environment. Typical applications include (Yang *et al.*, 2004; Frodigh *et al.*, 2000) battlefield and business section.

Regardless of the attractive applications, the features of MANET introduce several challenges that must be studied carefully before a wide commercial deployment can be expected. These include (Chlamtac *et al.*, 2003; Yang *et al.*, 2004), dynamic topologies, routing and power-constrained and operation

The versatility of TORA makes it ideal candidates for a wide-range array of applications. It can be used during natural disasters where there is no communication infrastructure as an extension of service coverage such as in airport hotspots and in normal enterprise deployment. A common use of TORA is during group communications in conferences. The key attributes that make TORA ideal candidates for such applications are it's quick self-configuration and low cost of deployment.

Emergency services: Search and rescue operations in the desert and in the mountain and so on. Replacement of fixed infrastructure in case of environmental disasters, policing, fire fighting, supporting doctors and nurses in hospitals.

Business sector: Ad-hoc network could be used for rescuing and emergency processes for adversity assistance struggles for instance, in flood, fire or earthquake. Emergency saving procedures should take place where damaged and non-existing transmissions structure and quick preparation of a transmission network is required (Chitkara and Ahmad, 2014).

Context aware services: Follow-on services: call-forwarding, mobile workspace, Information services: location specific services, time dependent services, Infotainment: touristic information.

Tactical networks: Military communication and military operations in the battlefields. Coverage extension: extending cellular network access and linking up with the internet, intranets and so on. Sensor networks: inside the home: smart sensors and actuators embedded in consumer electronics, Body Area Networks (BAN), data tracking of environmental conditions, animal movements, chemical/biological detection.

Home and enterprise networks: Using the wireless networking in home or office, conferences, meeting rooms theme parks, personal area networks.

Commercial and civilian environments: e-Commerce: electronic payments anytime and anywhere. Business: dynamic database access, mobile offices. Vehicular services: road or accident guidance, transmission of road and weather conditions, taxi cab network, inter-vehicle networks, sports stadiums, trade fairs, shopping malls and so on. Networks of visitors inside the airports.

Educational sector: Arrangement of communications facilities for computer-generated conference rooms or classrooms or laboratories (Chitkara and Ahmad, 2014).

Personal Area Network (PAN): Short-range MANET can simplify the intercommunication between various mobile devices (such as a mobile phone, laptops and wearable computers) (Sun, 2001).

Basic structure of TORA: The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive, efficient and scalable distributed routing algorithm based on the concept of link reversal (Park and Corson, 1997). The TORA has three elementary functions: Route creation, route maintenance and route erasure (Gupta *et al*., 2011). TORA can suffer from unbounded worst-case convergence time for very stressful scenarios (Park and Corson, 2000, 2001).

Creating a route from a given node to the destination requires establishment of a sequence of directed links leading from the node to the destination. The function is only initiated when a node with no directed links requires a route to the destination.

Thus, creating routes corresponds to assigning directions to links in an undirected network. The method used to accomplish this is a query/reply process which builds a Directed Acyclic Graph (DAG) rooted at the destination. The protocol uses QRY and RPY packets for this functionality. Maintaining routes refers to reacting to topological changes in the network in a manner such that routes to the destination are re-established within a finite time. This means that its directed portions returns to a destination-oriented DAG within a finite time.

Notation and assumptions: A network is modeled as a graph, G = (N, L) where, N is the finite set of nodes and L is a set of initially undirected links. Each node $i \in N$ is assumed to have a unique node Identifier (ID) and each link $(i, j) \in L$ is assumed to allow two-way communication (i.e, nodes connected by a link can communicate with each other in either direction). Due to mobility of the nodes, the set of links L is changing with time. From the perspective of neighbouring nodes, a node failure is equivalent to severing all links incident on that node. Each initially undirected link $(i, j) \in L$ may be subsequently be assigned one of the three states: undirected, directed from node i to node j, directed from node j to node i. If a link $(i, j) \in L$ is directed from node i to node j, node i is said to be "upstream" from node j while node j is said to be downstream from nodei. For each node i the neighbors of I, $N_i \subset N$ is defined to be the set of nodes j such that $(i, j) \in L$.

TORA requires the presence of an underlying link-level protocol which ensures that the node i is always aware of it's neighbours in the set N_i. It is also assumed that all transmitted packets are received correctly and in the order of transmission.

Route creation: Creating routes uses QRY and UPD packets. A QRY packet consists of a destination ID (did) which identifies the destination for which the algorithm is running. An UPD packet consists of a did and the height of the node i which is broadcasting the packet, H_i. Each node i (other than the destination) maintains a route requested flag, RR_i which is initially unset. Each node i (other than the destination) also maintains the time at which the last UPD packet was broadcast and the time at which each link $(i, j) \in L$ where $j \in N_i$ became active. When a node with no directed links and an unset route-requested flag requires a route to the destination it broadcasts a QRY packet and sets its route-requested flag. When a node I receives a QRY packet it reacts as follows:

If the route-requested flag of the receiving node is set, it discards the QRY packet. If the route-requested flag of the receiving node is not set and it's height is non-NULL with r = 0 it first compares the time last UPD packet was broadcast to the time the link over which the QRY packet received became active. If a UPD packet has been broadcast since the time the link became active it discards the QRY packet; otherwise, it broadcasts an UPD packet which contains it's current height. If the route-requested flag of the receiving node is not set and it's height is non-NULL with r = 0 but it has a neighbor node whose height is non-NULL with r = 0; it sets it's height to $H_i = (\tau_j, oid_j, r_j, \boldsymbol{\delta}_{j+1}, i)$ where $HN_{I, j}$ =

$(\tau_j, oid_j, r_j, \delta_j, j)$ is the minimum height of its non-NULL neighbors with $r = 0$, updates all the entries in it's link-state array LS and broadcasts a UPD packet which contains its new height. If none of the above conditions hold true, the receiving node re-broadcasts the QRY packet and sets its route-requested flag.

If a node has the route-requested flag set when a new link is established it broadcasts a QRY packet. When a node i receives a UPD packet from a neighbor $j \in N_i$, node i first updates the entry $HN_{i,j}$ in its height array with the height contained in the received UPD packet and then reacts as follows:

If the route-requested flag of the receiving node is set and the height contained in the received UPD packet is non-NULL with $r = 0$ it sets its height to $H_i = (\tau_j, oid_j, r_j, \delta_{j+1}, j)$ where $HN_{i,j} = (\tau_j, oid_j, r_j, \delta_j, j)$ is the height contained in the received UPD packet, updates all the entries in it's link-state array LS, unsets the route-required flag and then broadcasts an UPD packet which contains it's new height.

If the above condition does not hold true, the receiving node simply updates the entry $LS_{i,j}$ in it's link-state array.

Route maintenance: Route maintenance is only performed for nodes that have a non-NULL height. Furthermore, any neighbour's height which is NULL is not used for the computations. A node i is said to have no downstream links if $H_i < HN_{i,j}$ for all non-NULL neighbours $j \in N_i$. This will result in one of five possible reactions depending on the state of the node and the preceding event. Each node (other than the destination) that has no downstream links modifies it's height, $H_i = (\tau_i, oid_i, r_i, \delta_i, i)$ as follows:

Case 1 (Generate): Node i has no downstream links (due to a link failure). $(\tau_i, oid_i, r_i) = (t, i, 0)$ where t is the time of the failure. $(\delta_i, i) = (0, i)$, i.e., node i defines a new reference level. The above assumes that node i has at least one upstream neighbor. If node i has no upstream neighbors it sets it's height to NULL.

Case 2 (Propagate): Node i has no downstream links (due to a link reversal following the reception of a UPD packet) and the ordered sets (τ_j, oid_j, r_j) are not equal for all $j \in N_i$. $(\tau_i, oid_i, r_i) = \max\{(\tau_j, oid_j, r_j)/j \in N_i\}$ $(\delta_i, i) = \min\{(\delta_k \mid (\tau_k, oid_k, r_k) = \max [\tau_j, oid_j, r_j] \text{ for } j \in N_i)-1, i\}$ In essence, node i propagates the reference level of it's highest neighbor and selects a height which is lower than all neighbors with that reference level.

Case 3 (Reflect): Node i has no downstream links (due to a link reversal following reception of a UPD packet) and the ordered sets (τ_j, oid_j, r_j) are equal with $r_j = 0$ for all $j \in N_i$ $(\tau_i, oid_i, r_i) = (\tau_j, oid_j, 1)$ $(\delta_i, i) = (0, i)$. In essence, the same level (which has not been "reflected") has propagated to node i from all of its neighbors. Node i "reflects" back a higher sub-level by setting a bit r.

Case 4 (Detect): Node i has no downstream links (due to a link reversal following the reception of an UPD packet), the ordered sets (τ_j, oid_i, r_i) are equal with $r_j = 1$ for all $j \in N_i$ and $oid_j = i$ (i.e., node i defined the level). $(\tau_j, oid_i, r_i) = (-,-,-)$ $(\delta, i) = (-, I)$.

In essence, the last reference level defined by node i has been reflected and propagated back as a higher sub-level from all its neighbors. This corresponds to detection of a partition. Node i must initiate the process of erasing invalid routes.

Case 5 (Generate): Node i has no downstream links (due to link reversal following the reception of a UPD packet), the ordered sets (τ_j, oid_j, r_j) are equal with $r_j = 1$ for all $j \in N_i$ and $oid_j \neq i$ (i.e., node i did not define the level). $(\tau_i, oid_i, r_i) = (t, I, 0)$ where t is the time of failure $(\delta_i, i) = (0, i)$.

In essence, node i experienced a link failure (which did not require reaction) between the time it propagates a reference and the reflected higher sub-level returned from all neighbors. this is not necessarily a partition. Node i defines a new reference level.

Following the determination of its new height in cases 1-5, node i updates all the entries in the link-state array LS and broadcasts an UPD packet to all the neighbors $j \in N_i$. The UPD packet consists of a did and the new height of the node i which is broadcasting the packet, H_i. When a node i receives a UPD packet from a neighbor $j \in N_i$, node i updates the entries $HN_{i,j}$ and $LS_{i,j}$ in it's height and link-state arrays. If the update causes a link reversal which results in node i losing it's last downstream link then it modifies it's height as outlined as the cases above.

Route erasure: Following the detection of a partition, node i sets its height and the height entry for each neighbor $j \in N_i$, to NULL (unless the destination is a neighbor, in which case the corresponding height entry is set to ZERO), updates all the entries in it's link-state array LS and broadcasts a CLR packet. The CLR packet consists of a did and the reflected reference level of node i $(\tau_i, oid_i, 1)$. When a node i receives a CLR packet from a neighbor $j \in N_i$ it reacts as follows:

If the reference level in the CLR packet matches the reference level of node i it sets its height and the height entry for each neighbor $j \in N_i$ to NULL (unless the destination is a neighbor, i which case the corresponding height entry is set to ZERO), updates all the entries in its link-state array LS and broadcasts a CLR packet.

If the reference level in the CLR packet does not match the reference level of node i it sets the height entry for each neighbor $j \in N_i$ (with the same reference level as the CLR packet) to NULL and updates the corresponding link-state array entries.

Thus, the height of each node in the portion of the network which was partitioned is set to NULL and all invalid routes are erased. If condition 2 causes node i to lose it's last downstream link it reacts as in case 1 of route maintenance.

To implement the kernel of the architecture of the protocol designs: The simulations were performed using NetworkSimulator 2 (NS-2) (ISI, 2017),particularly popular in the ad hoc networking community. The traffic sources are CBR (continuous bit-rate). The source-destination pairs are spread randomly over the network. From the packet flow view, the processes run on a single node to change or "comment out" the existing protocols running in NS2; Protocols/Models supported by NS2. Routing: Unicast, multicast and hierarchical routing, etc. Transportation: TCP, UDP, others; traffic sources: web, ftp, telnet, cbr, etc., queuing disciplines: drop-tail, RED, etc., QoS: IntServ and DiffServ wireless networking and ad hoc routing and mobile, IP. NS2 Models: Traffic models and applications: web, FTP, telnet, Constant-Bit Rate (CBR), Transport protocols: Unicast: TCP (Reno,Vegas), UDP multicast, routing and queuing: wired routing, ad hoc routing, queuing protocols: RED (Random Early Drop), drop-tail, Physical media: Wired (point-to-point, LANs), wireless, satellites.

RESULTS AND DISCUSSION

The simulation results are obtained for TORA protocol. At low packet generation rate, less number of packets would be contending for the transmission therefore, throughput increases linearly and saturates at higher packet generation rate (Fig. 1-8).

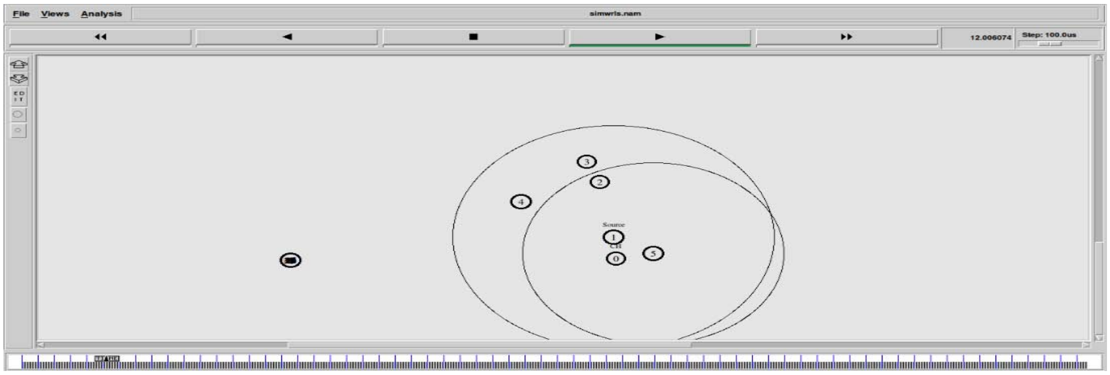

Fig. 1: Initial stage of arrangement of nodes in different cluster

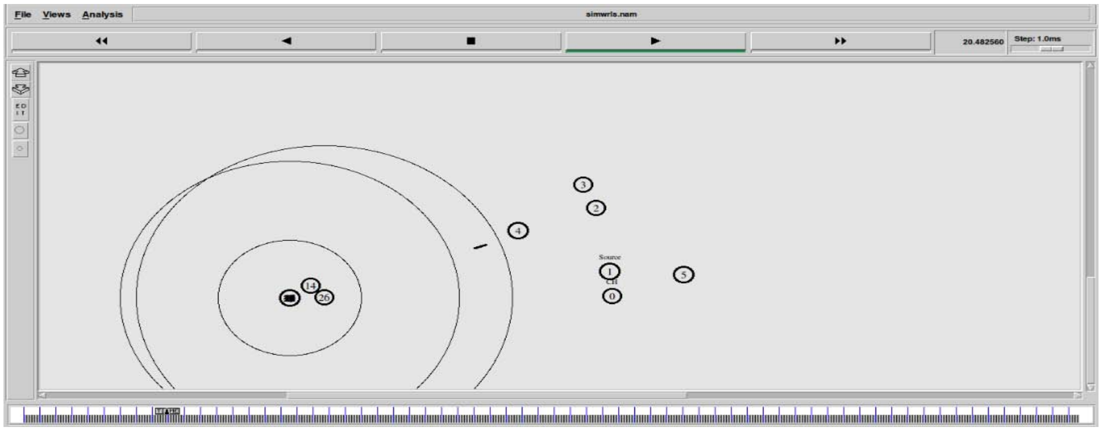

Fig. 2: Source node 1 transfer a packet to the destination with intermediate node

Fig. 3: Packet being dropped at the node due to congestion

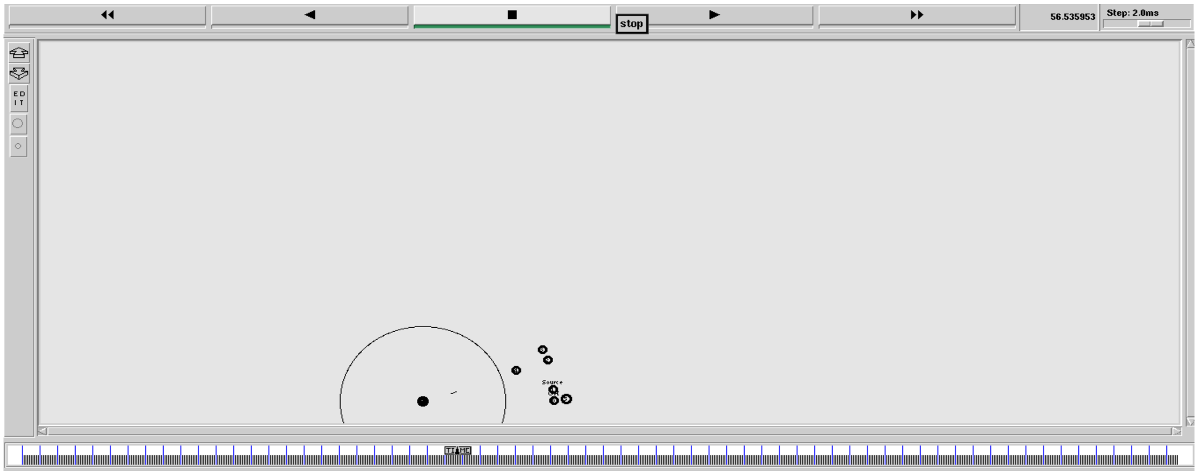

Fig. 4: Packet being dropped at the node is avoided

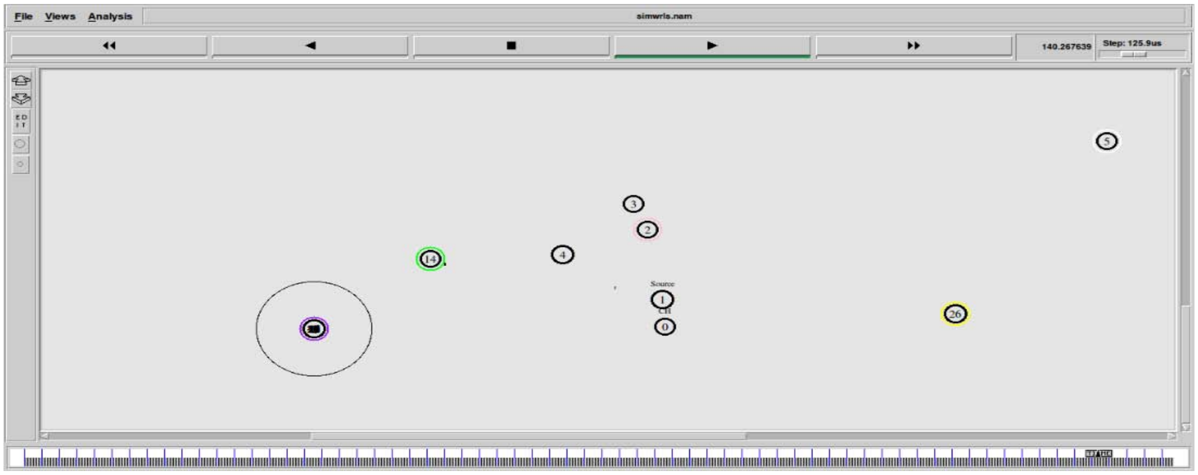

Fig. 5: Nodes with their energy levels

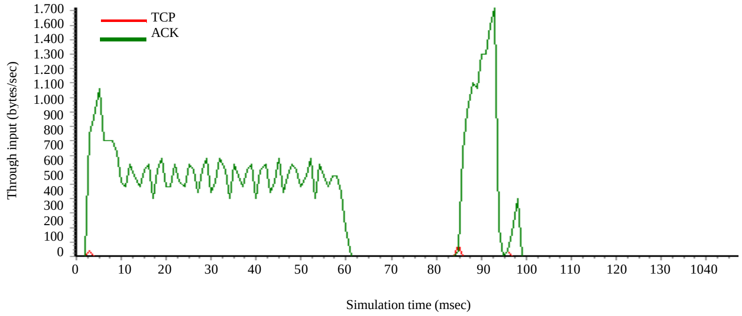

Fig. 6: Graph showing throughput vs. simulation time

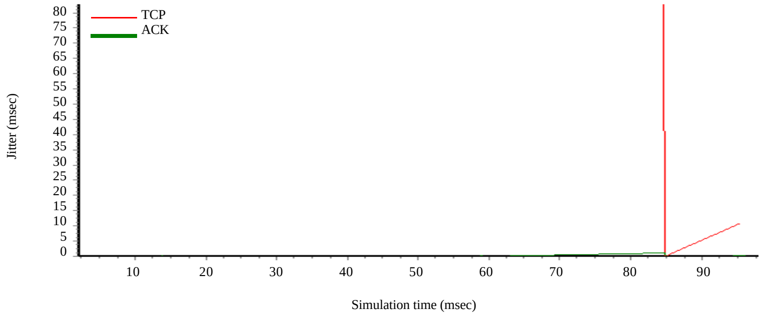

Fig. 7: Graph showing jitter vs. simulation time

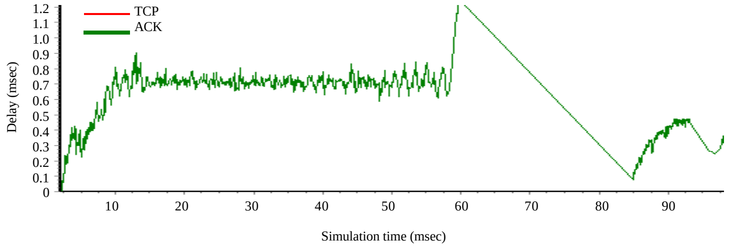

Fig. 8: Graph showing delay vs. simulation time

CONCLUSION

TORA works well considering the parameters throughput, jitter and delay. In wireless networks, congestion at a wireless node is related to congestion in it's one-hop neighbourhood, i.e., wireless networks are best treated as a union of neighbourhoods defined by the transmission radius of a node, rather than a graph consisting of nodes joined by point-to-point links. So, the congestion at a node is intrinsically related to congestion in its neighbourhood. A suitable mechanism needs to be incorporated in TORA to reflect this fact, so that, congested neighbourhoods can be avoided by QoS flows.

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