Towards a context sensitive and secure routing for in MANETs (Mobile Ad-hoc Networks)

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Abstract
Mobile **A**d-hoc **Net**works (**MANETs**) can be deployed quickly without any existing infrastructure. These networks are useful in many areas, such as emergency assistance, disaster relief, intelligent systems houses, patient monitoring, industrial applications, health monitoring, environmental control, military applications, etc. However ad-hoc networks face many challenges, such as the unpredictable mobility of the network, the limited amount of energy available, security challenges, low computational resources, low memory, etc. There is a need for routing approaches aware of those challenges. Thus, this work aims to provide a secure and context aware ad-hoc network, by changing the frequency of data transmission and routing the packets through reliable links. The proposed approaches has been tested, the results shows an interesting decrease of the transmission throughput coming from malicious nodes, a decrease in the packet loss and an increase of the network lifetime.

Keywords: Mobile ad-hoc networks, context aware routing, packet loss.

1. INTRODUCTION

The demand of smart phones, laptops and PDAs has grown exponentially each year since their introduction. These mobile devices can be used to form a MANET. A MANET consists of arbitrary deployed communicational devices such as cell phones, personal digital assistants (PDAs), laptops, etc; it is a wireless multi-hop network, where all nodes maintain network connectivity cooperatively. The mobile nodes are capable of connecting and communicating with each other using limited bandwidth radio links. These types of networks are useful in any situation where temporary network connectivity is required and in areas where there is no infrastructure, such as disaster relief where existing infrastructure is damaged or in military applications where a tactical network is necessary.

In the battlefield, typically in a foreign land, one may not rely on the existing infrastructure. In these situations, establishing infrastructure is not practical in terms of expenditure and time consumed. Hence, providing the needed connectivity and network services becomes a real challenge. In a wireless ad hoc network where pairs of mobiles communicate by exchanging a variable number of data packets along routes set up by a routing algorithm, reliability may be defined as the ability to provide high delivery rate, that is, to deliver most of the data packets in spite of faults breaking the routes or buffer overflows caused by overloaded nodes. Given the intrinsic nature of wireless ad hoc networks, reliability is a major issue.

A mobile Ad-hoc MANET topology can be defined as a dynamic (arbitrary) multi-hop graph G = (N, L), where N is a finite set of mobile nodes (MNs) and L is a set of edges which represent wireless links. A link (i, j) Є L exists if and only if the distance between two mobile nodes is less or equal than a fixed radius r. This r represents the radio transmission range that depends on wireless channel characteristics including transmission power. Accordingly, the neighborhood of a node x is defined by the set of nodes that are inside a circle (assume that MNs are moving in a two-dimensional plane) with center at x and radius r and it is denoted by the following equation:

$$Nr(x) = Nx = \{nf \mid d(x, nf) \leq r, x \neq \text{nf}, \forall \text{j} \in \text{N}, \text{j} \leq |\text{N}|\} \quad (1)$$

Where x is an arbitrary node in a graph G and d is a distance function. A path (or route) from node i to node j denoted by R_{ij} is a sequence of nodes R_{ij}= (i, n_1, n_2,… , n_k, j) where (i, n_1), (n_k, j) and (ny, ny+1) for 1≤ y ≤ k-1 are links. A simple path from i to j is a sequence of nodes with no node being repeated more than once. Due to the mobility of the nodes, the set of paths (wireless links) between any pair of nodes and distances is changing over time. New links can be established and existing links can vanish.

2. MANETS APPLICATIONS

MANETs are specifically designed for particular applications (Chlamtac and all, 2003). This section discusses potential applications which motivate deploying this kind of networks. MANETs can be used in collaborative networks, a typical application of a collaborative MANET can be considered as a conference room with participant's wishing to communicate with each other without the mediation of the global internet connectivity. In such scenario, a collaborative network can be set up among the participant's devices. Each participant can thus communicate with any other participant in the network without requiring any centralized routing infrastructure. These networks are thus collaborative in nature and are useful in cases where business network infrastructure is often missing or in scenarios where reduction in the cost of using infrastructure links is important.

MANETs can be used in distributed control systems, it allow distributed control with remote plants, sensors and actuators linked together through wireless communication. These networks help in coordinating unmanned mobile units and lead to a reduction in maintenance and reconfiguration costs. MANETs are used to coordinate the control of multiple vehicles in an automated highway system, coordination of unmanned airborne vehicles, and exploration of new geographical areas, rescue, medical applications, mobile systems in a conference and remote control of manufacturing units.

3. MOBILE AD-HOC NETWORKS CHALLENGES

In the battlefield, typically in a foreign land, one may not rely on the existing infrastructure. In these situations, establishing infrastructure is not practical in terms of expenditure and time consumed. Hence, providing the needed connectivity and network services becomes a real challenge. In a wireless ad hoc network where pairs of mobiles communicate by exchanging a variable number of data packets along routes set up by a routing algorithms, reliability may be defined as the ability to provide a high delivery rate, that is to deliver most of the data packets in spite of faults breaking the routes or buffer overflows caused by overloaded nodes. Given the intrinsic nature of wireless ad hoc networks, reliability is a major issue. Links failures may occur due to interferences on the wireless medium or most probably to nodes mobility, when pairs of nodes move out of the reciprocal transmission range or are shadowed by obstacles. MANETs do not only provide dynamic infrastructure networks but also allow the flexibility of wireless devices mobility.

Ad-hoc networks differ significantly from existing networks. First, the topology of the nodes in the network is dynamic. Second, these networks are self-configuring in nature and do not require any centralized control or administration. Such networks do not assume all the nodes to be in direct transmission range of each other. Hence these networks require specialized routing protocols that provide self-starting behavior. However energy constrained nodes, low channel bandwidth, node mobility, high channel error rates, and channel variability are some of the limitations of MANETs. Under these conditions, existing wired network protocols would fail or perform poorly. Thus, MANETs require specialized routing protocols. Operating power is one of the most important resources required by wireless devices (Min & Chinchuluun, 2006). For practical use, wireless devices can only store electricity in relatively small quantities. This makes it necessary to consider conservation measures that reduce consumption of electricity by the equipment.

In a related issue, current technology employed by batteries is not sufficient to power wireless devices for long periods. Thus, energy conservation is one of the few strategies that can really make a difference in the context of mobile device usage. Given the scarcity of power as an operational resource on mobile systems, it is important to notice that there is still no satisfactory solution that provides long-term service and/or low power consumption. In this work we propose an approach which tries to find the optimal path from source node to destination.

4. ROUTING PROTOCOLS

A protocol is a set of rules that must be followed by partners during a communication process. Without a protocol, messages sent on a network have no meaning, therefore, connection between nodes cannot be established and as result no information is transferred. Protocols are a required part of the logical structure of a computer network. There are many categories of routing protocols (figure 1). Proactive protocols (Guoyou, 2012) maintain fresh lists of destinations and their routes by periodically distributing routing tables throughout the network. Reactive protocols (Changling & Jörg, 2008) find a route on demand (only when needed) by flooding the network with Route Request packets. Studies show, that proactive protocols perform poorly when the mobility increase because of excessive routing overhead (Broch & all, 1998) and (Johansson & all, 1999).

5. PROBLEM STATEMENT

Despite of long history of MANETs, there are still a quite number of problems that are open for the research community. Routing is one of the most important open issues in mobile ad-hoc network's research. When nodes want to communicate with each other, they must initially discover a suitable route to be used for the communication. The high mobility, low bandwidth, and limited computing capability characteristics of mobile hosts make the design of routing protocols very challenging. The protocols must be able to keep up with the rapid unpredictable changes in network topology with as minimal control message exchanges as possible and in the most efficient and reliable way. An essential problem concerning ad hoc wireless networks is to design routing protocols allowing for communication between mobile hosts. The dynamic nature of ad hoc networks makes this problem especially challenging.

In any network communication there is a need for a suitable routing mechanism to deliver packets from source to destination nodes. The concept of routing can be described as the process of path finding. In case of mobile ad-hoc networks the main problem in routing mechanism, is how to send a packet from one node to another when no direct link exist between source and destination nodes. The routing protocol must also be aware of the mobile ad-hoc network's limitations. Using for example node's energy in a non-efficient way, may lead to some nodes death, which lead to breaking links and packets loss.

6. RELATED WORKS

Different approaches have been proposed in the research community to improve the reliability of packet-delivery in different application scenarios. **F**orward **E**rror **C**orrection (**FEC**) approaches (Gemmell & all, 2011), (Vicisano & Luby, 2011) and multipath transmission approaches (Stephen & all, 2011) are proposed to improve the reliability of packet-transmission by adding redundant information into transmitted data. With the redundant information, some bit errors can be eliminated without retransmission. Data-fusion mechanisms (Ye & all, 2003) can change the structure of data packets to distribute transmission errors across multiple packets. Geographical routing protocols (Jorge, 2011) use nodes location information to determine link status and avoid links between distant nodes. On-demand routing protocols (Georgy, 2011) check the status of links by exchanging a small control message before the transmission of any data packet. These approaches reduce the probability of transmitting a data packet through a link that has already failed.

Most proposed on-demand routing protocols (for example, Dynamic Source Routing (DSR) (rakesh & all, 2011) and **A**d hoc **O**n-demand **D**istance **V**ector (**AODV**) (Georgy, 2011), (Devi & Rhymend, 2011)) however, use single route for each session. SPAN (Chen & all, 2002) selects a number of coordinators to keep an ad hoc network connected. These coordinators are responsible for forwarding and buffering packets while others sleep. Thus it saves power without significantly diminishing the capacity or connectivity of the network. However it introduces large delays and is not applicable for time critical applications. Some routing algorithms given by (Min & Chinchuluun, 2006), (Jung & Vaidya, 2002) can optimize the energy use with a global perspective. But these algorithms cause expensive overheads for gathering, exchanging and storing the state information of a node. Power control techniques have direct impact on routing strategies for MANETs. Therefore, much of the work on power control has been concentrated on the development of new protocols that can minimize the used power.

For example, Jung and Vaidya (Jung & Vaidya, 2002) provide a new protocol for power control, based on information available through lower level network layers. Another example of this approach is given by (Narayanaswamy & all, 2005). A simple strategy for minimizing the power consumption in a network consists of trying to reach the state of minimum power in which the network is still connected. Despite the apparent optimality of this technique, (Park & Sivakumar, 2002) have shown that this is not necessarily an optimum power strategy for power control minimization. Still another approach for power control is presented by (Kawadia & Kumar 2003). Two protocols are proposed, in which the main technique used is clustering of mobile units according to some of its features.

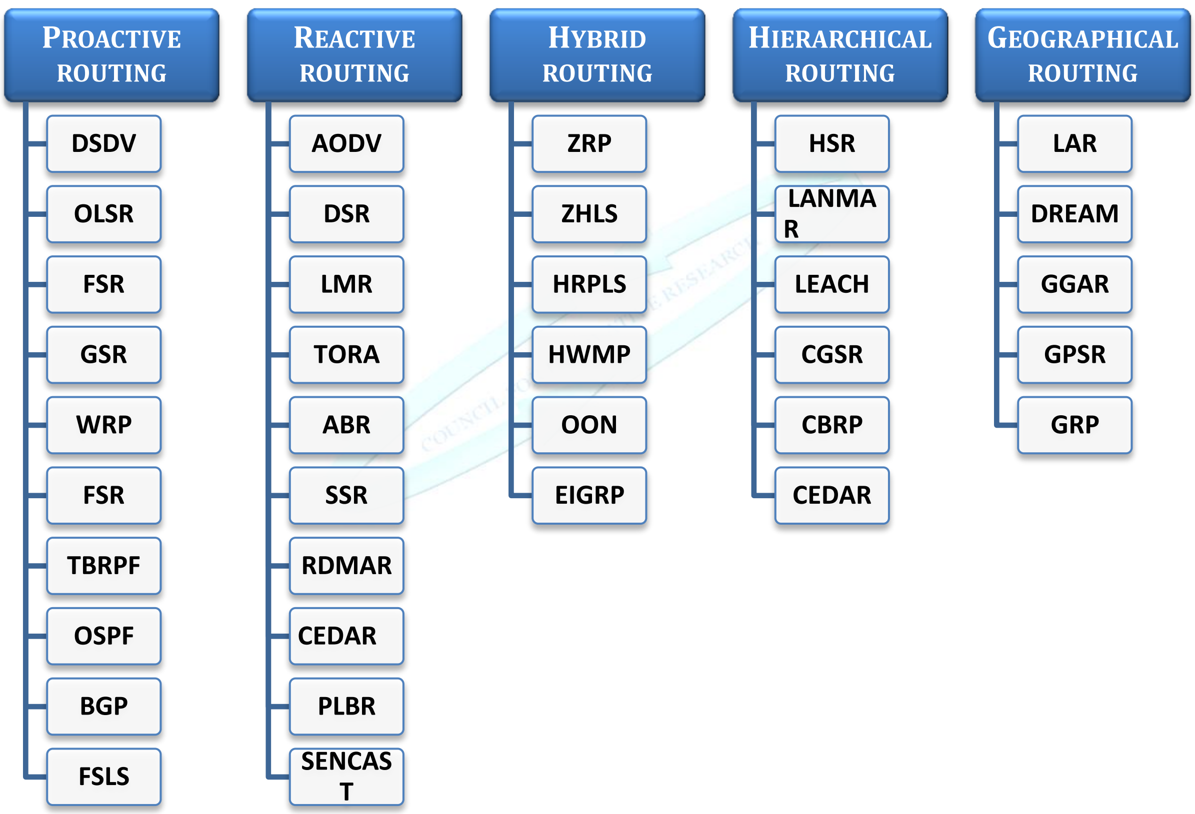

Figure 1. Routing protocols classification

7. APPROACH

If the motion parameters of two neighboring nodes like speed, direction, radio propagation range are known (using for example a **G**lobal **P**ositioning **S**ystem (**GPS**)), the duration of time these two nodes will remain connected can be determined. Assume two nodes i and j within the transmission range of each other. Let (xi, yi) be the coordinates of node i and (xj, yj) be the coordinates of node j. Let Vi and Vj be the speeds, ɵi ($0 \leq$ ɵi) and ɵj (ɵj $\leq 2\Pi$) be the directions of motion for nodes i and j, respectively. The amount of time two mobile hosts will stay connected, is predicted by the formula given by the following equation:

$$\textit{Link Time Life} = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$

(2)

$a = V(r)\cos\theta - V(s)\cos\theta$

$b = X(r) - X(s)$

$c = V(r)\sin\theta - V(s)\sin\theta = V(Y(r)) - V(Y(s))$

$d = Y(r) - Y(s)$

r is the transmission range of a wireless node with an Omni-directional antenna, which is 250 m. V(s) and V(r) are the velocities of the sender and receiver respectively. ϴ is the direction of motion of nodes. (Xs, Ys) and (Xr, Yr) are the coordinates of the sender and receiver respectively. Parameter "a" is the relative velocity of the receiver node with respect to the sender node along Y axis. "b" is the parameter used to determine the distance of the receiver node from the sender node along X axis. The third parameter used to determine the link time life is "c", which is the relative velocity of receiver node with respect to the sender node along Y axis. "d" is the distance of the receiver node from the sender node along Y axis. When a node wants to send data, it starts sending route request packets to find a path to the destination node. Our contribution is to add nodes velocity and energy information's in the route request packets which will allow the source node to send informations through nodes having the lowest velocity and the highest level of remaining energy.

Our approach also delete the route request messages when it reaches a node with low energy or high mobility speed and choose routers (intermediate nodes) having the lowest mobility speed and the highest remaining energy. Because the nodes having a high mobility speed can leave the range transmission of their neighbors easily and the nodes having very a low remaining energy can die at any moment, which causes a link break. The fact of not acting as a router will help the node having a critical level of power to not consume additional energy by routing data packets, but it can continue to play its motion detection role in the case of a military network of wireless sensors for example. When the destination node receives the first route request packet, it starts a timer, at the end of this timer the destination node uses the equations (3) and (4) to select the path having the lowest velocity and highest level of remaining energy. Where **APV** represents the **A**ssigned value according to the **P**ath **V**elocity, **ANV**(i) is the **A**ssigned value according to the **N**ode i **V**elocity and **HC** means **H**op **C**ount. **APE** represents the **A**ssigned value according to the **P**ath remaining **E**nergy and **ANE**(i) means the **A**ssigned value according to the **N**ode i **E**nergy.

$$\boldsymbol{APV} = \sum_{i=2}^{n-1} \frac{\boldsymbol{ANV(i)}}{\boldsymbol{HC}} \qquad (3)$$

$$\boldsymbol{APE} = \sum_{i=2}^{n-1} \frac{\boldsymbol{ANE(i)}}{\boldsymbol{HC}} \qquad (4)$$

When a node wants to send data to a specific destination, it triggers a route discovery process, by broadcasting route request packets, in order to know how to reach the destination node. We have added two fields to the route request packets: **APV** (**A**ssigned value according to the **P**ath **V**elocity) and **APE** (**A**ssigned value according to the **P**ath remaining **E**nergy). In the source node APV=APE=0, then the route request packet collect an assigned value according to the velocity and remaining energy of the intermediate nodes. If the intermediate node velocity is low or its remaining energy is high, this node will have a high assigned value (APV and APE), otherwise, if the intermediate node's velocity is high or its remaining energy is low, this node will have a low assigned value. When the destination node receives the route request packet, it chooses the path having the highest assigned value.

8. SIMULATION

We use the NS-2 simulator (Kevin & Kannan, 2010). Figure 2 gives a simplified View of NS-2. NS-2 takes as an input a TCL file (in which we implement the scenario). NS2 consists of two key languages: C++ and Object-oriented Tool Command Language (OTcl). While the C++ defines the internal mechanism of the simulation objects, the OTcl sets up simulation by assembling and configuring the objects as well as scheduling discrete events.

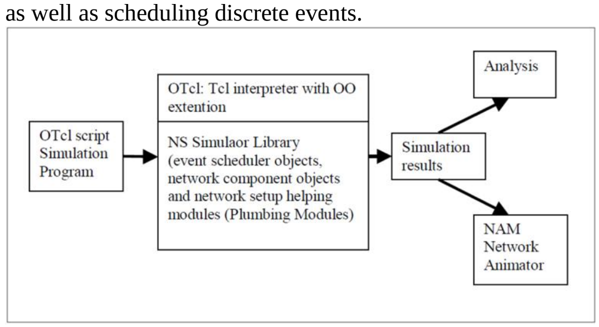

Figure 2. Simplified view of NS2

NS2 is an object oriented, discrete event driven network simulator. It is written in C++ and OTcl (Object-oriented Tool command language) script language with Object-oriented extensions developed at MIT (Massachusetts Institute of Technology). In order to reduce the processing time, the basic network component objects are written using C++. Each object has a matching OTcl object through an OTcl linkage. The procedure of using NS-2 (Kawdia & Kumar, 2003) to simulate the network and analyze the simulation result is as follows. Firstly, the user has to program with OTcl script language to initiate an event scheduler, set up the network topology using the network objects and tell traffic sources when to start and stop transmitting packets through the event scheduler. OTcl script is executed by NS2. The simulation results from running this script in NS2 include one or more text based output files and an input to a graphical simulation display tool called Network Animator (NAM).

Text based files record the activities taking place in the network. It can be analyzed by other tools such as Gwak and Gnuplot to calculate and draw the results such as delay and jitter in form of figures. NAM is an animation tool for viewing network simulation traces and real world packet traces. It has a graphical interface which can present information such as number of packets drops at each link. After simulation, NS2 outputs a trace file, which can be interpreted by many tools, such as NAM and Xgraph. We create a simulation scenario using NS-2 Scenario Generator (Jia & Hamid, 2011). We use the Java-Trace-Analyzer to interpret the trace file generated by the simulation. Our approach was simulated using a previous version of our secure and context aware routing protocol (Haboub & Ouzzif, 2012). Figure 3 shows that the proposed approach reduce packet loss.

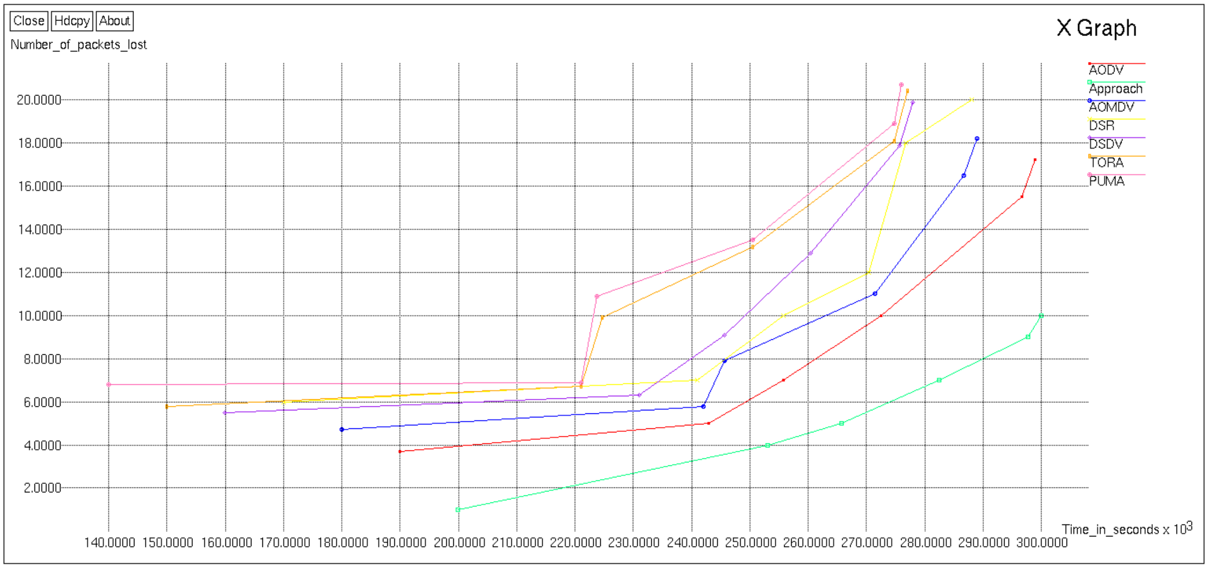

Figure 3. Packet loss versus time

9. CONCLUSION AND FUTURE WORKS

In this work we propose an approach to reduce packet loss in MANETs by avoiding conditions in which packet losses are likely, by using a context-aware routing technique, which selects the suitable routing path from source node to destination, according to nodes states. For future work we plan to use more experimentation metrics (such as nodes power, mobility, transmission delay, network vicinity, etc.). We also plan to consider more criteria like connectivity, and so on. We also plan to use formal verification techniques with the **SPIN** (**S**imple **P**romela **IN**terpreter) tool, as a mean to guarantee the quality of the proposed routing approaches. Formal verification is a technique that assures a system has, or has not, a given propriety, based on a formal specification of the system under evaluation. This technique has proved to be a valuable tool, even contradicting some author's claims and informal proofs.

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