Link-Stability and Energy Aware Routing in Wireless Sensor Networks

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Abstract - MOBILE ad hoc networks (MANETs) have attracted a lot of attention due to the popularity of mobile devices and the advances in wireless communication technologies. A MANET is a peer-to-peer multihop mobile wireless network that has neither a fixed infrastructure nor a central server. Each node in a MANET acts as a router, and communicates with each other. The mobility constraints of mobile nodes may lead to cause problem in link stability. On the other hand, in order to support node mobility. scalable routing strategies have been designed and these protocols try to consider the path duration in order to respect some QoS constraints and to reduce the route discovery procedures. Often energy saving and path duration and stability can be two contrasting efforts and trying to satisfy both of them can be very difficult. A scalable routing protocol called LAER, based on the joint metric of link stability and energy drain rate, has been proposed. It is based on the local topology knowledge and it makes use of a greedy technique based on a joint metric and a modified perimeter forwarding strategy for the recovery from local maximum. The main aim of this work is to propose an optimization routing model within a MANET. The model attempts to minimize simultaneously the energy consumption of the mobile nodes and maximize the link stability of the transmissions, when choosing paths for individual transmissions. The idea of considering, at the same time, energy consumption and link stability is motivated by the observation that most routing protocols tend to select shorter routes, in this way high efficiency in using wireless bandwidth and increase path stability are ensured. However, such routes may suffer from higher energy consumption, since higher transmission ranges are needed. We enhance our work to detect the selfish node present in the network, providing wrong information about their energy and recent data access details. Due to such wrong information we should reroute our packet delivery path. Such selfish nodes do not consume any energy such as CPU power, battery and also bandwidth for retransmitting the data of other nodes and they reserve them only for themselves. Every node in a MANET calculates credit risk information on other connected nodes individually to measure the degree of selfishness.

Index Terms - MANET, QoS, Sensor, LAER, Link Stability.

1. INTRODUCTION

Energy is an important resource that needs to be preserved in order to extend the lifetime of the network. The link and path stability among nodes allows the reduction of control overhead and can offer some benefits also in terms of energy saving over ad hoc networks. However the selection of more stable routes under nodes mobility can lead to the selection of shorter routes. This is not always suitable in terms of energy consumption. On the other hand, sometimes trying to optimize the energy can lead to the selection of more fragile routes. Thus, it is evident that both the aforementioned parameters (i.e., link stability associated with the nodes mobility and energy consumption) should be considered in designing routing protocols, which allow right trade-off between route stability and minimum energy consumption to be achieved.

The main aim of this work is to propose an optimization routing model within a MANET. The model attempts to minimize simultaneously the energy consumption of the mobile nodes and maximize the link stability of the transmissions, when choosing paths for individual transmissions. The idea of considering, at the same time, energy consumption and link stability is motivated by the observation that most routing protocols tend to select shorter routes, in this way high efficiency in using wireless bandwidth and increase path stability are ensured. However, such routes may suffer from higher energy consumption since higher transmission ranges are needed.

The link stability probability has been defined on the basis of the random mobility model. A formal model to predict the lifetime of a routing path, based on the random walk mobility and on the prediction technique. It considers a probability model derived through the subdivision into cells of the area where mobile nodes move and on the observations of node movements in these cells. Transition probabilities are calculated and a state-based model of the movement among the cells is considered. Each connection between a mobile node in

a cell and the other mobile nodes among its neighbour cells is considered as the state of the wireless link. In this way, the wireless link dynamic is determined between a mobile node and its neighbours permitting the calculation of the link lifetime. After this assumption of independent link failure, the route breakage probability is derived.

Other techniques rely on the use of special devices such as the Global Positioning System (GPS) to detect the exact position of the mobile nodes. Each node can calculate its position and a protocol is applied which disseminates or requests the position for the other nodes. This approach is also criticized, because in some environments such as indoors or where the mobile nodes are greatly limited in energy, the GPS is not functional. Some enhanced versions of GPSR have been presented where some movement prediction is applied in order to reduce the effect of bad location information; however, these fully location-based routing schemes do not account jointly for other metrics such as energy and stability.

The path stability, in terms of the number of route transitions a routing protocol incurs to continue the data exchange is considered. End-to-end delay of a source destination session is another considered performance metric particularly for real-time applications. The prediction location-based routing scheme increases the delivery ratio of GPSR and selects the more stable route. However, such as for the previous listed contributions, energy is not considered in the packet forwarding.

- 1.1 Applications of the domain
- 1. In Public WLAN provides campus-wide indoor and outdoor coverage.
- 2. It provides flexible solution to implement the information delivery system required to control transportation services.
- 3. Wildlife monitoring focuses on tracking wild species to deeply investigate their behaviour and understand the interactions and influences on each other, as well as their reaction to the ecosystem changes caused by human activities.
- 4. Opportunistic networks can provide intermittent Internet connectivity to rural and developing areas where they typically represent the only affordable way to help bridging the digital divide.
- 5. VANETs use ad hoc communications for performing efficient driver assistance and car safety. The communications include data from the roadside and from other cars. VANET research aims to supply drivers with information regarding obstacles on the road and emergency events, mainly due to line-of-sight limitations and large processing delays. VANET can be used to communicate premonitions, notification of emergencies, and warnings about traffic conditions.

6. The underwater wireless sensor network have applications including the scientific (e.g., oceanographic data collection for scientific exploration, pollution control, or climate monitoring), military (e.g., tactical surveillance), and civilian fields (e.g., tsunami warnings).

1.2 Problem statement

Based on the local knowledge of the neighbourhood, the heuristic determines that the next hop toward destination is selected among the neighbour nodes that maximize (minimize) the joined link-stability energy metric.

This local criterion permits a high scalability to be offered to the routing algorithm in terms of state info storage and control packets transmission sent by any underlying routing protocol to maintain the network state knowledge. On the basis of previous considerations, the main contributions of this manuscript are the following:

- A multiobjective mathematical formulation for the joint stability and energy problem is presented.
- The proposed protocol is based on a geographic paradigm different by other routing protocols accounting for joint metrics such as PERRA.
- Adoption of a novel stability metric is based on the residual link lifetime concept. This metric is considered more robust because it is independent on the transmission radius and node speed parameters that can be affected by measurement errors.
- A novel energy aware-metric adopted in our previous contributions has been introduced in the proposed optimization model in order to consider not only the residual energy but also its time variation associated with the traffic load.

1.3. Objective of the project

- To minimize simultaneously the energy consumption of the mobile nodes and maximize the link stability of the transmissions when choosing paths for individual transmissions.
- To detect the selfish node present in the network providing wrong information about their energy and recent data access details

1.4. Scope of the project

Each wireless node has the capability of forwarding an incoming packet to one of its neighbouring nodes and to receive information from a transmitting node. In addition, each node is able to identify all its neighbours through protocol messages. It is assumed that each node does not enter in standby mode and each node can overhear the packet inside its transmission range and it is not addressed to itself.

The LAER algorithm requires each node to advertise its location, rate of energy consumption and link stability index for each link outgoing by node. We will insert the information mentioned above in LAER HELLO packet. Each node broadcasts HELLO packets to all its neighbours that are in its communication range. Each node in LAER maintains the table of its direct neighbours. When a node receives the HELLO packet, it updates the information of the neighbour, if neighbour ID is already present in table or adds neighbour information, if it is a new neighbor.

2. LITERATURE REVIEW

1. Title: The Effect of Mobility-induced Location Errors on Geographic Routing in Mobile Ad Hoc and Sensor Networks.

Author: Dongjin Son, Ahmed Helmy, Bhaskar Krishnamachari Introduction

In geographic routing, the packet forwarding decision is solely based on the location information of neighbors and a destination node at the moment of forwarding. Geographic routing protocols have been shown to be correct and efficient with exact location information. The effect of location errors on geographic routing, however, has not been studied before to our knowledge. Hardware non ideality and harsh environment in sensor networks can cause location inaccuracy even without node mobility. This effect is exacerbated with node mobility and harder to resolve because each node may have a different level of loc ation error according to its mobility level.

Issues in existing system

Three main factors that greatly affect the performance of geographic routing protocols:

- (a) The freshness of location information: It is not possible to avoid the time gap between the measurement of a location and the time when this information is actually used for a routing decision, in both proactive and reactive routing protocols. This is because of the latency involved in the delivery of location information, and also because the time interval between locations updates is generally longer than the inter-packet arrival times.
- (b) The speed of mobile nodes in the network: Each mobile node can move at a different speed, and the maximum node speed is another critical factor deciding the level of inaccuracy.
- (c) The mobility pattern of mobile nodes: If the node movement exhibits a different pattern, the effect of node mobility on the geographic routing protocol will be different. Four different mobility models are adopted in our work: Random waypoint (RWP), Freeway (FWY), Manhattan (MH) and Reference Point Group Mobility (RPGM).

Geographic routing in GPSR or the algorithm described is a location-based routing protocol for wireless networks, and consists of two packet forwarding modes: greedy packet forwarding and perimeter forwarding. The originator of the data generates a packet that contains the coordinates of the destination node. Initially, the packet is forwarded by greedy packet forwarding in which each node makes a localized routing decision based on the location information of its neighbour nodes as follows. Every node periodically broadcast a beacon packet within its own radio range which carries a node id and current location information. Every node which receives a beacon packet stores received information in the neighbour list. Every time a node forwards a packet, it calculates the distances from every neighbour node to the destination node. The neighbour node located closest to the destination node is selected as a next hop. With this localized routing decision a packet can be delivered to the destination through the optimal path in the distance aspect. However, there are some situations called local maxima where a node cannot find any node located closer to the destination while there exist a detour through a neighbour located further from the destination than itself.

When a node finds out a local maximum situation, the packet forwarding mode is changed to perimeter forwarding. The packet then traverses along faces of a planar subgraph using the right-hand rule until it reaches a node that is closer to the destination than the node where greedy forwarding first failed due to the local maximum. At this point, the packet forwarding mode returns to greedy packet forwarding.

In the Random Waypoint (RWP) mobility model, nodes are randomly placed within the simulation field at starting time. Each node selects a destination randomly, independent of other nodes, to which it moves with a constant speed picked randomly from [0,V max]. When a node reaches the destination, it stays there for a given pause time before it starts to move to another random destination. The RWP model is simple and easy to use, but it does not take into consideration the following three main characteristics of realistic mobility in ad hoc networks: 1) spatial correlation between different nodes where movement of one node depends on the movement of neighboring nodes, 2) temporal correlation for each node, where a node's speed and direction depends on its previous movement history.

The Freeway mobility model emulates the motion behavior of mobile nodes on a freeway. An example of the freeway model is shown in figure 1. Each mobile node is restricted to its lane on the freeway and the velocity is temporally dependent on its previous velocity. If two mobile nodes on the same freeway lane are within the Safety Distance (SD), the velocity of the following node cannot exceed the velocity of preceding node. Due to the above relationships, the Freeway mobility model provides temporal correlation and geographic restriction, and

in general the nodes also exhibit high spatial correlation. In this mobility model the links between nodes moving in the same direction remain for a relatively long time while link duration between nodes moving in opposite directions is low.

Geographic routing has been introduced in mobile ad hoc networks and sensor networks. Under ideal settings, it has been proved to provide drastic performance improvement over strictly address-centric routing schemes. While geographic routing has been shown to be correct and efficient when location information is accurate, its performance in the face of location errors is not well understood. In this paper, we study the effect of inaccurate location information caused by node mobility under a rich set of scenarios and mobility models. We identify two main problems, named LLNK and LOOP that are caused by mobility-induced location errors. Based on analysis via ns -2 simulations, we propose two mobility prediction schemes such as neighbor location prediction (NLP) and destination location prediction (DLP) to mitigate these problems

Advantages of proposed system

LLNK and LOOP problems proposed a two-part mobility prediction scheme to address these three main factors, (1) maximum node speed (2) beacon interval (3) mobility pattern that affect the performance of geographic routing. It clarify the effect of these factors on the performance of location based routing protocols.

With NLP, the number of lost link problems can be significantly decreased by estimating the actual location of neighbor nodes based on latest movement and by excluding nodes located outside of a sender's radio transmission range. With DLP, unnecessary packet drops near the destination can be avoided, and the positive side of node mobility is exploited while the negative effect is mitigated.

2. Title: Scalable Ad Hoc Routing in Large, Dense Wireless Networks Using Clustering and Landmarks

Author: Xiaoyan Hong, Mario Gerla, Yunjung Yi, Kaixin Xu and Taek Jin Kwon

Introduction

Routing in mobile ad hoc networks include new generation of On Demand ad hoc routing schemes and efficient proactive routing protocols. The on demand routing schemes (including AODV [1], DSR [2], TORA [3] and ABR [4], etc.) compute routes only when needed, without incurring the O/H if there is no data traffic. Small Query/Reply packets are used to discover (possible more than one) route to a given destination. Proactive routing schemes, such as traditional link state and distance vector routing (e.g., OSPF, RIP) compute global routes in the background using routing information updated through periodical or triggered exchanges. The benefits of proactive

routing include low latency route access, alternate path support and ability to proactively monitor the quality of the (alternate) paths for effective call acceptance control. These properties make proactive schemes (in particular, Link State (LS)) desirable for applications that include real time communications and QoS guarantees.

Issues in existing system

Destination-Sequenced Distance Vector (DSDV) is a distance vector type routing scheme using Distributed Bellman-Ford algorithm. The destination sequenced sequence numbers are used to prevent the forming of routing loops. The updates generated by a node (the"destination") are sequentially numbered. Upon receiving an update (for a given destination), a node will accept it only if it contains a sequence number larger than the previously received updates. The control overhead generated by DVDS is generally lower than link state type protocols because it exchanges smaller distance vectors than link state updates. The DSDV protocol uses both periodic and triggered routing updates to keep routing information fresh at mobile nodes. In a mobile environment triggered updates may generate very high routing overhead

Optimized Link State Routing Protocol (OLSR) is a link state routing protocol. The protocol uses multi-point relays (MPRs) to reduce the number of "superfluous" broadcast packet retransmissions and also to reduce the size of the LS update packets. A node, say node A, periodically broadcasts HELLO messages to all immediate neighbors to exchange neighbourhood information (i.e., list of neighbors) and to compute the Multi- Point Relay set (MPR). The optimum (minimum size) MPR computation is NP complete. Efficient heuristics are used. By construction, only the relay nodes need to forward the LS updates in order to guarantee dissemination in the entire network. In a further effort to reduce routing O/H, the LS update of node A is also reduced in sizes as it includes only the neighbors that select node A as one of their MPR nodes. This leads to a reduced LS packet size and traffic O/H.

In Landmark Ad Hoc Routing, we address the scalability issue in two directions. The first direction involves "dense" ad hoc networks, where a node is within radio range of a large number of neighbors. In this case, when a node issues a control packet that must be broadcast to the entire network via "flooding" (e.g., link state update message), all the neighbors will receive and in turn forward the message. This forwarding is often "superfluous" in that only a few (say, four to six) neighbors are strictly required to forward the message so that the rest of the network receives it. Yet, superfluous forwarding can cause intolerable traffic O/H in the network and must thus be curbed. The other direction concerns large scale networks with a very large number of nodes geographically distributed over a large terrain. Large network size leads to large routing tables and high control traffic O/H. Large tables have implications in node storage and processing O/H. And traffic O/H reduces the usable

network capacity. The two aspects - density and large scale are actually related through power control. By increasing node transmit power, we can reduce the number of hops to destinations and thus reduce the "scale" factor of the network. But we increase this way the network density. On the other hand, we may reduce power to the minimum acceptable to maintain the network connected. We would improve frequency reuse this way. But, we may end up violating the end to end delays of some applications. There are clearly complex, application dependent tradeoffs that influence the choice of power level in an ad hoc network. It is safe to say, however, that the node density or large scale problems cannot be solved simply adjusting transmission power. Systematic approaches that are integrated with the routing algorithm must be sought. The passive clustering deals with node density. The clustering structure designates a subset of nodes (cluster heads and gateways) as forward routers, thus reducing broadcast flood control overhead.

Advantages of proposed system

- The advantage of using passive (instead of active) clustering is that the physical cluster structure can be built without extra control messages and it guarantees no isolated partitions of the network.
- 3. Title: Lifetime Prediction Routing in Mobile Ad Hoc Networks

Author: Morteza Maleki, Karthik Dantu, and Massoud Pedram Introduction

A mobile adhoc network is one where in all nodes work independent of any common centralized admin. Each one of them performs the tasks of a router. They should be self-adapting in that if their connection topology changes, their routing tables should reflect the change. Also, since they are mobile, they largely run on finite batteries. This means that they are power-constrained. Hence, it is an important design constraint for them to be power aware or minimal in power expenditure. Also, each node should not be greedy about its own power since failure of some nodes in the network might result in lack of connectivity between nodes

Issues in existing system

The main disadvantage of the problem formulation of reference is that it always selects the least-power cost routes. As a result, nodes along these least-power cost routes tend to "die" soon because of the battery energy exhaustion. This is doubly harmful since the nodes that die early are precisely the ones that are needed most to maintain the network connectivity (and hence useful service life). Therefore, it will be better to use a higher power cost route if this routing solution avoids using nodes that have a small amount of remaining battery energy. This observation has given rise to a number of "battery-cost

lifetime-aware routing" algorithms as described next. Minimum battery cost routing algorithm minimizes the total cost of the route. More precisely, this algorithm minimizes the summation of inverse of remaining battery capacity for all nodes on the routing path. Min-Max battery cost routing algorithm is a modification of the minimum battery cost routing. This algorithm attempts to avoid the route with nodes having the least battery capacity among all nodes in all possible routes. Thereby, it results in smooth use of the battery of each node. The Conditional Max-Min battery capacity routing algorithm was proposed. This algorithm chooses the route with minimal total transmission power if all nodes in the route have remaining battery capacities higher than a threshold; otherwise, routes that consist of nodes with the lowest remaining battery capacities are avoided. Several experiments have been performed to compare different battery cost-aware routing in terms of the network lifetime. According to their reported results, the minimum battery cost routing exhibited superior results compared to the Min-Max battery cost routing in terms of the expiration times of the nodes in the network. Conditional Min-Max routing showed better or worse results depending on how the threshold value was chosen.

Maximum Residual Packet Capacity (MRPC) was proposed. MRPC is conceptually similar to the conditional Min-Max battery cost, but MRPC identifies the capacity of a node not just by the residual battery capacity, but also by the expected energy spent in reliably forwarding a packet over a specific link lifetime prediction is that mobility introduces different dynamics into the network. The lifetime of a node is a function of residual energy in the node and energy to transmit a bit from the node to its neighbors. However, it is very difficult to efficiently and reliably compute this metric when we have mobility since the location of the nodes and their neighbors constantly change. PSR does not use prediction and only uses the remaining battery capacity. We believe LPR is superior to PSR since LPR not only captures the remaining (residual) battery capacity but also accounts for the rate of energy discharge. This makes the cost function of LPR more accurate as opposed to just using battery capacity. This is true in MANETs since mobility can change the traffic patterns through the node, which thereby affects the rate of depletion of its battery. Also, recent history is a good indicator of the traffic through the node and hence we chose to employ lifetime prediction.

Advantages of proposed system

 Our approach is a dynamic distributed load balancing approach that avoids power-congested nodes and chooses paths that are lightly loaded. This helps LPR achieve minimum variance in energy levels of different nodes in the network 4. Title: Routing Protocol for Ad Hoc Mobile Networks using Mobility Prediction

Author: Werner Creixell and Kaoru Sezaki

Introduction

Mobility introduces uncertainty in future nodes positions and consequently in the network topology as well. The node can then send and receive packets from other nodes. The node has also the capacity to relay packets that are not destined to the node itself. This capacity makes the MANET substantially different from other wireless networks. In the MANET the nodes can construct a path in the network using the routing capacity of intermediate nodes. In other words the communication is established in a wireless multi-hop fashion. The node can also have other characteristics such as small size and battery powered, making the node not only mobile but also portable. As a result MANET can operate in places and situations where traditional networks cannot work properly, such us in disaster recovery areas, rural zones, and third world countries.

Issues in existing system

In Pedestrian Trajectory Tracking, the data used in this paper was taken in an experiment conducted in a train station on central Tokyo. To track pedestrian movement a set of single-row laser range scanners were placed in the train station. Each scanner can measure distance through a rotating laser beam, by software it is possible to distinguish moving objects from static ones. Prediction Based Routing Algorithm help in the forward decisions of our proposal. For that purpose each node implements the prediction method by itself, then the prediction calculation is made any time the position is updated. For simplicity we assumed that the position is updated periodically. Since the method calculation is done recursively there is no need for the node to keep a large storage for the prediction calculation.

In the proposed algorithm each node informs its position to its neighbours nodes by sending beacon packets periodically. The proposal uses the beacon packets to send the current position and the predicted position as well. As a consequence each node knows its neighbours position and an estimation of their future positions.

Advantages of proposed system

- The proposed novel geographical routing protocol based on mobility prediction. The proposed protocol shares the good characteristic of Ellipsoid protocol such as simplicity and ability to operate in a three dimensional space.
- The proposed protocol had the better performance shows that mobility affects more to the other protocols

because they are "not aware" of this fact. They take decisions assuming the nodes are static.

5. Title: Energy Efficient Routing Protocols for Mobile Ad Hoc Networks

Author: Chansu Yu Ben Lee Hee Yong Youn

Introduction

Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature. In particular, energy efficient routing may be the most important design criteria for MANETssince mobile nodes will be powered by batteries with limited capacity. Power failure of a mobile node not only affect the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime.

For protocols that belong to the former category, the active communication energy can be reduced by adjusting each node's radio power just enough to reach the receiving node but not more than that. This transmission power control approach can be extended to determine the optimal routing path that minimizes the total transmission energy required to deliver data packets to the destination. For protocols that belong to the latter category, each node can save the inactivity energy by switching its mode of operation into sleep/power-down mode or simply turns it off when there is no data to transmit or receive. This leads to considerable energy savings, especially when the network environment is characterized with low duty cycle of communication activities. However, it requires well-designed routing protocol to guarantee data delivery even if most of the nodes sleep and do not forward packets for other nodes. Another important approach to optimizing communication energy is load distribution approach. While the primary focus of the above two approaches is to minimize energy consumption of individual nodes, the main goal of the load distribution method is to balance the energy usage among the nodes and to maximize the network lifetime by avoiding over-utilized nodes when selecting a routing path

Issues in existing system

The routing protocols proposed for MANETs are generally categorized as table-driven and on-demand driven based on the timing of when the routes are updated. With table-driven routing protocols, each node attempts to maintain consistent, up-to-date routing information to every other node in the network. This is done in response to changes in the network by having each node update its routing table and propagate the updates to its neighboring nodes. Thus, it is proactive in the sense that when a packet needs to be forwarded the route is already known and can be immediately used. As is the case for wired networks, the routing table is constructed using either link-state or distance vector algorithms containing a list of all

the destinations, the next hop, and the number of hops to each destination. Many routing protocols including Destination-Sequenced Distance Vector (DSDV) and Fisheye State Routing (FSR) protocol [20] belong to this category, and they differ in the number of routing tables manipulated and the methods used to exchange and maintain routing tables. With on demand driven routing, routes are discovered only when a source node desires them.

Route discovery and route maintenance are two main procedures: The route discovery process involves sending route-request packets from a source to its neighbor nodes, which then forward the request to their neighbors, and so on. Once the route-request reaches the destination node, it responds by unicasting a route-reply packet back to the source node via the neighbor from which it first received the route-request. When the route-request reaches an intermediate node that has a sufficiently up-to-date route, it stops forwarding and sends a route-reply message back to the source. Once the route is established, some form of route maintenance process maintains it in each node's internal data structure called a route-cache until the destination becomes inaccessible along the route. Note that each node learns the routing paths as time passes not only as a source or an intermediate node but also as an overhearing neighbour node. In contrast to table-driven routing protocols, not all up-to-date routes are maintained at every node. Dynamic Source Routing (DSR) [21] and Ad-Hoc On-Demand Distance Vector (AODV) [22] are examples of on-demand driven protocols.

OMM (Online Max-Min Routing) Protocol

FAR maximizes the network lifetime when data generation rate is known. The OMM protocol achieves the same goal without knowing the data generation rate in advance. It optimizes two different metrics of the nodes in the network: Minimizing power consumption (min-power) and maximizing the minimal residual power (max-min). The second metric is helpful in preventing the occurrence of overloaded nodes.

PLR (Power-aware Localized Routing) Protocol

Routing algorithms based on global information, such as data generation rate or power level information of all nodes (node costs), may not be practical because each node is provided with only the local information. The PLR protocol is a localized, fully distributed energy aware routing algorithm but it assumes that a source node has the location information of its neighbors and the destination. It is equivalent to knowing the link costs from itself to its neighbors and to the destination. Based on this information, the source cannot find the optimal path but selects the next hop through which the overall transmission power to the destination is minimized

Advantages of proposed system

- It facilitate communication within a MANET, an efficient routing protocol is required to discover routes between mobile nodes
- A mobile ad hoc network (MANET) consists of autonomous, self-organizing and self-operating nodes, each of which communicates directly with the nodes within its wireless range or indirectly with other nodes via a dynamically computed, multi-hop route

6. Title: Exploring the Performance Tradeoffs among Stability-Oriented Routing protocols for Mobile Ad hoc Networks

Author: Natarajan Meghanathan

Introduction

Mobile ad hoc networks (MANETs) are dynamic distributed systems, in which any node can become a source or destination for a communication session and all nodes are considered as peers. The transmission range of the nodes is often limited and hence routes between any two nodes in MANETs are often multi-hop in nature with several intermediate nodes forwarding the data of their peers. Several routing protocols have been proposed in the MANET literature. These protocols select routes either proactively or reactively. Proactive routing protocols attempt to determine routes between any two pairs of nodes, irrespective of their requirement, using periodic exchange of link state updates. Reactive routing protocols tend to determine routes only when required, i.e., in an on-demand fashion, using a broadcast query and reply cycle. Even though, there is a route discovery and maintenance overhead in both classes of protocols, research studies (e.g., [3]) have shown that in dynamic scenarios typical to that of MANETs, reactive ondemand routing protocols are to be preferred compared to the class of proactive routing protocols.

Path stability is an important design criterion to be considered in the development of multi-hop routing protocols for resourceconstrained environments like that of MANETs. Wireless links are shared and are limited in their bandwidth. Frequent route discovery attempts could congest the network and also knock out the battery power at critical nodes. The battery reserves at the nodes are to be treated precious as they may be deployed in environments where recharging is next to impossible. Also, nodes in energy-constrained environments like that of the sensor networks and embedded networks cannot afford to lose their battery power quickly. For multi-media applications that require the packets to be delivered in-order with negligible variance in the inter-packet delay, frequent changes in the routes traversed by the packets could result in out-of-order packet delivery with high jitter. In the case of reliable data transfer applications, failure to receive an acknowledgement packet within a particular timeout interval can also trigger retransmissions at the source side. As a result, the application layer at the receiver side might be overloaded in handling outof-order, lost and duplicate packets. Thus, path stability is important from the point of view of Quality of Service too.

Issues in existing system

FORP utilizes the mobility and location information of nodes to approximately predict the expiration time (LET) of a wireless link. The minimum of the LET values of all wireless links on a path is termed as the route expiration time (RET). The route with the maximum value of the RET is selected. Each node is assumed to be able to predict the LET values of each of its links with its neighboring nodes based on the information regarding the current position of the nodes, velocity, the direction of movement, and transmission ranges FORP assumes the availability of location-update mechanisms like GPS (Global Positioning System) to identify the location of nodes and also assumes that the clocks across all nodes are synchronized.

The node mobility model used in all of our simulations is the Random Waypoint model is widely used mobility model in MANET simulation studies. According to this model, each node starts moving from an arbitrary location to a randomly selected destination location at a speed uniformly distributed in the range [vmin,...,vmax]. Once the destination is reached, the node may stop there for a certain time called the pause time and then continue to move by choosing a different target location and a different velocity.

The energy consumption at a node in an ad hoc network can be divided into three categories: (1) Energy utilized for transmitting a message, (2) Energy utilized for receiving a message and (3) Energy utilized in idle state. In [12], it has been shown that in the presence of overhearing, no real optimization in the energy consumption or the node lifetime can be achieved. That is, the energy consumption at a node would be dominated by the energy lost when the node is in the idle state (also referred to as being in the promiscuous mode). Thus, in this paper, we do not consider the energy lost in the idle state and focus only on the energy consumed during the transmission and reception of messages (data packets, the MAC layer

RTS-CTS packets and the periodic beacons), and energy consumed due to route discoveries

Advantages of proposed system

- RABR reduces this tradeoff to a certain extent by maintaining a proper balance between the route propagation load and route stability.
- FORP routes are the most stable of the three protocols but also incur the highest delay and energy consumption per packet because of the increase in the number of intermediate nodes that forward a packet.

7. Title: GPSR: Greedy Perimeter Stateless Routing for Wireless Networks

Author: Brad Karp and H. T. Kung

Introduction

Hierarchy is the most widely deployed approach to scale routing as the number of network destinations increases. Without hierarchy, Internet routing could not scale to support today's number of Internet leaf networks. An Autonomous System runs an intra-domain routing protocol inside its borders, and appears as a single entity in the backbone interdomain routing protocol, BGP. This hierarchy is based on well-defined and rarely changing administrative and topological boundaries. It is therefore not easily applicable to freely moving ad-hoc wireless networks, where topology has no well-defined AS boundaries, and routers may have no common administrative authority.

Issues in existing system

Caching has come to prominence as a strategy for scaling adhoc routing protocols. When their cached topological information becomes out-of-date, these routers must obtain more current topological information to continue routing successfully. Caching reduces the routing protocols' message load in two ways: it avoids pushing topological information where the forwarding load does not require it (e.g., at idle routers), and it often reduces the number of hops between the router that has the needed topological information and the router that requires it (i.e., a node closer than a changed link may already have cached the new status of that link).

Johnson andMaltz propose the Dynamic Source Routing (DSR) protocol. DSR generates routing traffic reactively: a router floods a route request packet throughout the network. When the request reaches the destination, the destination returns a route reply to the request's originator. Nodes aggressively cache routes that they learn, so that intermediate nodes between a querier and destination may subsequently reply on behalf of the destination, and limit the propagation of requests

Li et al. propose GLS, a scalable and robust location database that geographically addresses queries and registrations. Their system dynamically selects multiple database servers to store each node's location, for robustness against server failure. This property also ensures that a cluster of nodes partitioned from the remainder of the network continues to have location database service, provided by nodes inside the cluster. GLS uses a geographic hierarchy to serve queries at a server topologically close to the querier.

Bose et al. independently investigated the graph algorithms for rendering a radio network's graph planar. They suggest the Gabriel Graph, and analyze the increase in path length over shortest paths when traversing a graph using only perimeters. Motivated by the longer-than-optimal paths perimeter traversal alone finds, they suggest combining planar graph traversal with greedy forwarding and verify that this combination produces path lengths closer to true shortest paths. They do not present a routing protocol, do not simulate a network at the packet level, and assume that all nodes are stationary and reachable.

Advantages of proposed system

- Greedy Perimeter Stateless Routing, GPSR, a routing algorithm that uses geography to achieve small pernode routing state, small routing protocol message complexity, and extremely robust packet delivery on densely deployed wireless networks.
- GPSR's benefits all stem from geographic routing's use of only immediate-neighbor information in forwarding decisions. Routing protocols that rely on end-to-end state concerning the path between a forwarding router and a packet's destination
- 8. Title: Securing Location Aware Services over VANET Using Geographical Secure Path Routing

Author: Vivek Pathak and Danfeng Yao

Introduction

Geographic routing is an established protocol for routing in adhoc networks. It relies on nodes knowing their geographic locations, and using their one-hop neighbours for routing messages to target geographic destinations. Modern vehicles typically have an on-board GPS device. This makes geographic routing particularly suitable for routing in a VANET. Similar to other personal wireless devices, in VANET vehicles are typically used by a single person or family. Therefore, location privacy is usually a concern for people when using the services provided by VANET.

VANETs are also vulnerable to malicious nodes and other adversaries because there is no central coordinator, which makes it hard to impose admission control. The routing mechanism and the routed data both can be attacked. Securing location aware services in VANETs while simultaneously protecting location privacy is an interesting problem.

Issues in existing system

Secure routing in ad-hoc networks has been investigated by a number of prior works. Hu and Perrig propose the Ariadne protocol for securing on-demand and source routing protocols in ad-hoc networks. Similarly, the SEAD protocol secures distance vector routing in ad-hoc networks. Both the protocols requires a secure cryptographic initialization phase, but use highly efficient symmetric key cryptography. While our approach uses expensive modular arithmetic, it does not require secure initialization.

A multi-hop anonymous challenge mechanism has been used by Mahajan et. al. for detection of free riders in ad-hoc wireless network. Their mechanism requires two-hop transmission of challenge messages. A scheme based on secure cryptographic initialization is presented by Liu et. al is to provide robust location estimation for sensor nodes in a hostile environment. Our approach is distinguished in the sense that we do not require any secure initialization.

The proposed geographical secure path routing (GSPR) protects adhoc routing against malicious nodes and passive adversaries. The routing protocol operates on location aware anonymous nodes to provide privacy preserving secure geographic routing for ad-hoc networks. The protocol has the following goals:

- Route messages to desired geographic locations in the presence of malicious nodes. Detect and avoid bad geographic regions containing malicious or faulty nodes.
- Authenticate self-generated public keys and geographic locations of nodes on the routing path.

Advantages of proposed system

- Geographical secure path routing protocol requires associative cryptographic one-way hash functions for security. These hash functions are derived from the discrete logarithm problem which uses expensive modular arithmetic.
- The secure routing protocol also authenticates the public key and the geographic location of destination nodes.
- 9. Title: Minimum Energy Mobile Wireless Networks

Author: Volkan Rodoplu, Student Member, IEEE, and Teresa H. Meng, Fellow, IEEE

Introduction

The network protocol not only maintains a globally connected network in spite of possible module failure, but also defines the major power management strategy based on low-power RF transceiver design. Minimum energy consumption in portable communication devices has been one of the major design goals, if not the most important one, in recent IC designs. In wireless communication systems, the need for low power becomes even more pronounced when designing RF transceivers for small-sized portable user sets.

Applications where minimum energy networking can effect significant benefits include the digital battlefield, where soldiers are deployed over an unfamiliar terrain, and multisensory networks, where sensors communicate with each other with no base station nearby. Even in the presence of base stations such as in cellular phone systems, minimum energy

network design can allow longer battery life and mitigate interference

Issues in existing system

The proposed position-based algorithm is to set up and maintain a minimum energy network between users that are randomly deployed over an area and are allowed to move with random velocities. We denote these mobile users by "nodes" over the two-dimensional plane. Our network protocol reconfigures the links dynamically as nodes move around, and its operation does not depend on the number of nodes in the system.

Each mobile node is assumed to have a portable set with transmission, reception, and processing capabilities. In addition, each has a low-power global positioning system (GPS) receiver on board, which provides position information within at least 5 m of accuracy. The recent low-power implementation of a GPS receiver makes its presence a viable option in minimum energy network design

Advantages of proposed system

- The distributed protocol finds the minimum power topology for a stationary ad hoc network.
- The topology via a local search is found in each node's in mobile adhoc network.

10. Title: Routing Protocol For Mobile Ad Hoc Networks Using Mobility Prediction

Author: W. Creixell and K. Sezaki

Introduction

The MANET is compound by mobile nodes carried by people. The nodes can relay information to other nodes by wireless ports. The network is established by multi-hop wireless links. Since nodes can be battery powered, the network can work in scenarios where there is no infrastructure like rural areas, third world countries or disaster areas. Nodes mobility is one of the MANET characteristics that has a bigger influence in the whole system performance. Mobility affects most of the parts of the system and its influence must be considered in the design process.

Issues in existing system

The proposal of this work consists in a geographical routing protocol, it means the forwarding decisions are based only in the position of the nodes. The proposed algorithm is based on a position prediction method Creixell and Sezaki. As a consequence we will focus our previous work discussion to those two areas, mobility prediction and geographical routing. There is some proposal to use prediction in ad hoc networks routing, for example in Su et al (4) a simple prediction method is used. In their work they calculate Dt the time that nodes i and

j will stay connected. This method has the disadvantage of assuming that the nodes have simple mobility patters, no sudden direction changes and constant velocity. These assumptions are clearly unrealistic. This method does not calculates the future position of the nodes i and j, it only estimates the disconnection time Dt. Consequently has not been used in geographical routing protocols.

Various geographical routing protocol has been proposed like in Bae andd Vaida (LAR) and in Basagni et al (DREAM), but these approaches are flooding base, therefore they waste network resources. A more interesting approach are Greedy Perimeter Stateless Routing (GPSR) Karp and Kungand the ellipsoid in Yamazaki and Sezaki. These two algorithm utilizes only neighbour information making a efficient usage of network resources.

Advantages of proposed system

- The proposed a novel geographical routing protocol based on mobility prediction.
- The proposed protocol shares the good characteristic of Ellipsoid protocol such as simplicity and ability to operate in a three dimensional space
- The proposed algorithm does mobility prediction which improves network performance.

3. SYSTEM ANALYSIS

3.1 Existing System

Energy is an important resource that needs to be preserved in order to extend the lifetime of the network; on the other hand, the link and path stability among nodes allows the reduction of control overhead and can offer some benefits also in terms of energy saving over ad hoc networks. However, as will be shown in this contribution, the selection of more stable routes under nodes mobility can lead to the selection of shorter routes. This is not always suitable in terms of energy consumption. On the other hand, sometimes, trying to optimize the energy can lead to the selection of more fragile routes. Thus, it is evident that both the aforementioned parameters (i.e., link stability associated with the nodes mobility and energy consumption) should be considered in designing routing protocols, which allow right tradeoff between route stability and minimum energy consumption to be achieved.

Five different metrics, for stable path selection, have been proposed in the literature: the first technique is based on the local choice of the oldest link as the most stable link; the second class of metrics concerns the selection of the youngest links, because they are considered more resilient to breakage; the third criterion is based on the selection of the link with the highest average residual lifetime value; the fourth one makes selection of the link with the highest persistence probability; finally, the fifth metric focuses on the connection failure

probability. The latter approach has been shown to be robust because it is based on the monitoring of the links lifetime of the mobile nodes in the wireless network, in the past and in the present, to predict its behavior, in the future without considering directly parameters depending by underlying mobility model such as node speed or direction. The path stability, in terms of the number of route transitions a routing protocol incurs to continue the data exchange. End-to-end delay of a source destination session is another considered performance metric, particularly for real-time applications.

3.2 Disadvantages of Existing System

- Considering oldest ant newest node for routing is not efficient for path stability.
- Routing is done based on shortest path not include energy awareness.
- Life time of node is not considered for data transmission.

3.3 Proposed System

In the proposed system our contribution on the multiobjective mathematical formulation of a routing scheme, which considers two metrics that is stability and energy. However, in this first contribution, only the optimization problem was formulated, whereas no analysis on the protocol management and protocol performance has been carried out This local criterion permits a high scalability to be offered to the routing algorithm in terms of state info storage and control packets transmission sent by any underlying routing protocol to maintain the network state knowledge. On the basis of previous considerations, the main contributions of this manuscript are the following:

- 1. A multiobjective mathematical formulation for the joint stability and energy problem is presented.
- 2. The proposed protocol is based on a geographic paradigm, different by other routing protocols accounting for joint metrics, such as PERRA.
- Adoption of a novel stability metric based on the residual link lifetime concept. This metric is considered more robust than the metric proposed in because it is independent on the transmission radius and node speed parameters that can be affected by measurement errors.
- 4. A novel energy aware-metric, adopted in our previous contributions, has been introduced in the proposed optimization model in order to consider not only the residual energy but also its time variation associated with the traffic load.
- 5. The multiobjective routing algorithm is integrated in the scalable routing protocol and its performance is

tested through simulations and comparison with PERRA, GPSR and an enhanced version of GPSR called Ellipsoid algorithm-based GPSR (E-GPSR).

We enhance our work to detect the selfish node by self-replica allocation. Use those replica we devise novel replica allocation techniques with the developed selfish node detection method. They are based on the concept of a self-centered friendship tree (SCF-tree) and its variation to achieve high data accessibility with low communication cost in the presence of selfish nodes. The SCF-tree is inspired by our human friendship management in the real world. In the real world, a friendship, which is a form of social bond, is made individually. For example, although A and B are friends, the friends of A are not always the same as the friends of B. With the help of SCFtree, we aim to reduce the communication cost, while still achieving good data accessibility. The technical contributions of this paper can be summarized as follows.

- Recognizing the selfish replica allocation problem: We view a selfish node in a MANET from the perspective of data replication, and recognize that selfish replica allocation can lead to degraded data accessibility in a MANET.
- Detecting the fully or the partially selfish nodes effectively: We devise a selfish node detection method that can measure the degree of selfishness.
- Allocating replica effectively: We propose a set of replica allocation techniques that use the self-centered friendship tree to reduce communication cost, while achieving good data accessibility.
- Verifying the proposed strategy: The simulation results verify the efficacy of our proposed strategy.

After building the SCF-tree, a node allocates replica at every relocation period. Each node asks nonselfish nodes within its SCF-tree to hold replica when it cannot hold replica in its local memory space. Since the SCF-tree based replica allocation is performed in a fully distributed manner, each node determines replica allocation individually without any communication with other nodes.

3.4 Advantages of Proposed System

- Energy aware routing provides durable link stability in MANET.
- A node that provides duplicate information about recent data accessibility and energy resources are handled by our enhancement.
- Routing is not based on shortest path it's about energy aware and link so path efficiency is more and durable.

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4. SYSTEM SPECIFICATION

4.1 Hardware Requirements

Processor : Pentium IV 2.4 GHz

Hard Disk : 80 GB RAM : 256 MB

Video : 800 x 600 resolutions, 256 colors

4.2 Software Requirements

Operating System : Windows XP and above Front end : NS2 simulator

4.3 Software Description

About NS2 simulator

NS2 become familiar to analyse some of the simulated objects. It Configure, run and analyse simulations for wireless networks as well as for interacting TCP flows. Network Simulator version 2 (NS-2) is a free and open source discrete event network simulator developed at UC Berkeley. You can add your own protocol, contribute to the code and from time to time, you need to troubleshoot some of the bugs. NS is a discrete event simulator where the advance of time depends on the timing of events which are maintained by a scheduler.NS-2 works under Linux, Mac, and Windows. NS-2 has a large and rich library of network and protocol objects. It covers a large part of applications (Web, FTP, CBR. .) protocols (transport and routing protocols), network types (Satellite links, wired and wireless LAN), network elements (mobile nodes, wireless channel models, link and queue models,...) and traffic models (exponential, uniform, . . .). NS-2also allows to add and test new protocols and applications and/or to modify existing ones.

NS-2 is based on an object oriented simulator written in C++ and OTcl interpreter (an object oriented extension of Tool Command Language TCL). These different objects are written in C++ code in order to achieve efficiency in the simulation and faster execution times. (e.g. Implementation of IEEE 802.11 is found in . . . ns-**/ns-**/mac/802_11.cc,h). The OTcl script, which is provided by the user at the simulation time, is used to define and to configure the network topology and network elements (node type, the protocols and applications to be used), and to schedule the events.

The OTcl scripts are used also to tell NS to create a visualization trace as well as an ASCII file trace corresponding to the events generated in the network. To analyse the trace files, other independent tools will be needed to filter, compute and display the results (e.g. Awk, Matlab, gnuplot, etc...). Two other independent and optional tools are provided with NS packages: Network animator (Nam) and xgraph. OTcl scripts can be written in any text editor like kate or emacs.

5. SYSTEM IMPLEMENTATION

5.1 Implementation List

- 1. Develop the MANET Network
- 2. Implement the Link-Stability Aware Metric
- 3. Implement the Energy-Aware Metric
- 4. Finding Selfish node
- 5. Handling selfish node using replica Method.
- 6. Performance evaluation (comparing to existing system)

5.2 Modules Description

1. Develop the MANET Network:

A wireless network is simulated, with minimum of 30 nodes moving in defined area. Each node moves randomly in this area, with a speed selected in a range $[0, v_{max}]$ with no pause time. Between mobile hosts there are 8 and 16 CBR/UDP sources generating 8 packets/s (with a packet size of 512 bytes). The duration of each simulation is 700 seconds. To extract average values, we simulated each scenario five times.

To have detailed energy-related information over a simulation, the ns-2 code was modified to obtain the amount of energy consumed (energy spent in transmitting, receiving) over time. In this way, accurate information was obtained about energy at every simulation time to evaluate the protocols from the energetic point of view.

2. Implement the Link-Stability Aware Metric

A statistical-based approach has been adopted in order to discriminate among several links which are more stable for some periods of time without exactly predicting the residual link lifetime of each link. Thus, to enable mobile devices to make smart decisions in relationship to the stability, a practical method is used, based exclusively on observations related to the link, in previous time instants. As a result, this analysis produces an evaluation of the link residual lifetime of the link, since the stability of a link is given by its probability of persisting for a certain time span. The link residual lifetime represents the potential remaining time that the link can exist before breaking. The expected residual life time $R_{i,j}$ ($a_{i,j}$) of a link (i,j) of age ($a_{i,j}$) is determined from the collected statistical data as follows:

$$R_{i,j}(a_{i,j}) = \frac{\sum_{a=a_{ij}}^{A_{\max}} a \cdot d[a]}{\sum_{a=a_{ij}}^{A_{\max}} d[a]} - a_{i,j} \, \forall (i,j) \in A,$$

Where a_{max} represents the maximum observed age of the links and d is an array of length $a_{max}+1$ used to store the observed data.

In particular, d is determined through a sampling of the link ages every fixed time interval and its generic component d[a] represents the number of links with age equal to a. The coefficient $R_{i,j}\left(a_{i,j}\right)$ is defined as the ratio between the sum, on all links with age equal or greater than $(a_{i,j})$ of the products of the age a and the number of links with age equal to a (that is d[a]), over the total number of links with age greater or equal to $a_{i,j}$.

3. Implement the Energy-Aware Metric:

It is assumed that each wireless node has the capability of forwarding an incoming packet to one of its neighboring nodes and to receive information from a transmitting node. In addition, each node is able to identify all its neighbors through protocol messages. It is assumed that each node does not enter in standby mode and each node can overhear the packet inside its transmission range and it is not addressed to itself.

The energy needed to transmit a packet p from node i is $E_{tx}(p,i) = I \cdot v \cdot t_b$ Joules, where I is the current (in Ampere), v the voltage (in Volt), and t_b the time taken to transmit the packet p (in seconds). The energy E(p,i) spent to transmit a packet from node i to node j is given by

$$E(p,i) = E_{tx}(p,i) + E_{rx}(p,j)$$

Where E $_{tx}$ and E $_{rx}$ denote respectively, the amount of energy spent to transmit the packet from node i to node j and to receive the packet at node j; to the energy spent to overhear the packet has been avoided in this context. The power dissipated by mobile nodes to exchange beaconing messages and/or to remain always in active modality is also considered.

4. Finding Selfish node:

At a specific period, or relocation period, each node executes the following procedures:

- Each node detects the selfish nodes based on credit risk scores (CR).
- Each node makes its own (partial) topology graph and builds its own SCF-tree by excluding selfish nodes.
- Based on SCF-tree, each node allocates replica in a fully distributed manner.

The CR score is updated accordingly during the query processing phase to effectively measure the "degree of selfishness".

Credit Risk
$$=\frac{expected\ risk}{expected\ value}$$
.

A node wants to know if another node is believable, in the sense that a replica can be paid back, or served upon request to share a memory space in a MANET. With the measured degree of selfishness, a novel tree that represents relationships among nodes in a MANET is proposed for replica allocation termed the SCF-tree. The key strength of the SCF-tree-based replica allocation techniques is that it can minimize the communication cost, while achieving high data accessibility. This is because each node detects selfishness and makes replica allocation at its own discretion, without forming any group or engaging in lengthy negotiations.

```
Algorithm 1. Pseudo code to detect selfish nodes
00: At every relocation period
01: /*N_i detects selfish nodes with this algorithm */
02: detection(){
03:
      for (each connected node N_k ){
          if (nCR_i^k < \delta)N_k is marked as non-selfish;
04.
          else N_k is marked as selfish;}
05:
06:
     wait until replica allocation is done;
07:
     for (each connected node N_k){
08:
          if (N_i has allocated replica to N_k){
09
            ND_i^k = the number of allocated replica;
10.
            SS_i^k = the total size of allocated replica;
11:
          else{
12:
            ND_i^k = 1;
13:
            SS_i^k = the size of a data item;
```

Algorithm 2. Pseudo code to update selfish features

```
00: At every query processing time
```

```
01: /* When N_i issues a query */
02: update_SF(){
     while (during the predefined time \omega){
04:
         if (an expected node N_k serves the query)
            decrease P_i^k;
05:
               if (an unexpected node N_i serves the query){
      06:
      07:
                   ND_i^j = ND_i^j + 1;
      08:
                   SS_i^j = SS_i^j + \text{ (the size of a data item);}
      09:
            } }
            if (an expected node N_k does not serve the query){
      10:
      11:
                    increase P_i^k;
                    ND_i^k = ND_i^k - 1;
      12:
                    SS_i^k = SS_i^k – (the size of a data item);
      13:
```

5. Handling selfish node using replica Method:

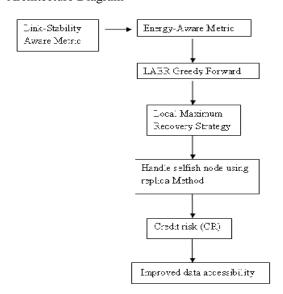
After building the SCF-tree, a node allocates replica at every relocation period. Each node asks nonselfish nodes within its SCF-tree to hold replica when it cannot hold replica in its local memory space. Since the SCF-tree based replica allocation is

14: } }

performed in a fully distributed manner, each node determines replica allocation individually without any communication with other nodes.

```
Algorithm 4. Pseudo code for replica allocation
00: /*N_i executes this algorithm at relocation period */
01: replica_allocation(){
02: L_i = \text{make\_priority}(T_i^{SCF});
03: for (each data item \in \mathbb{D}_i){
04: if (M_s \text{ is not full})
         allocate replica of the data to M_s;
05:
06: else{/*M_s is full */
07:
         allocate replica of the data to the target node;
         /* the target node is selected from L_i^*/
08:
 09:
         if (M_p \text{ is not full})
 10:
            allocate replica of the data to M_p; } }
 11: while (during a relocation period){
 12: if (N_k \text{ requests for the allocation of } D_q)
       replica_allocation_for_others (N_k, D_q); } }
 14: Procedure make_priority (T_i^{SCF}) {
 15: for (all vertices in T_i^{SCF}){
 16: select a vertex in T_i^{SCF} in order of BFS;
 17: append the selected vertex id to L_i; }
18: return L_i; }
19: Procedure replica_allocation_for_others(N_k, N_k)
20: if (N_k \text{ is in } T_i^{SCF} \text{ and } N_i \text{ does not hold } D_q)
21: if (M_p is not full) allocate D_q to M_p; 22: else{/*M_p is full */
23:
     if(N_i holds any replica of local interest in M_p)
24:
      replace the replica with D_q;
25:
     else{
26:
      /*N_h is the node with the highest nCR_i^h
      among the nodes which allocated replica to M_p^*
27:
        if (nCR_i^h > nCR_i^k)
          replace the replica requested by N_h with D_g;
28:
29: } } }
```

5.3. Architecture Diagram



6. CONCLUSION AND FUTURE WORK

A scalable routing protocol called LAER is based on the joint metric of link stability and energy drain rate has been proposed. It is based on the local topology knowledge and it makes use of a greedy technique based on a joint metric and a modified perimeter forwarding strategy for the recovery from local maximum. Its performances have been compared with other three protocols proposed in literature such as GPSR, E-GPSR, and PERRA. LAER protocol inherits the scalability of GPSR and E-GPSR, improving the performance in terms of node selection with higher link duration when a higher weight is given to the stability index and a higher residual energy is given to energy aware index.

LAER outperforms PERRA in terms of control overhead and in terms of a higher capability to balance traffic load due to the minimum drain rate metric included in the joint metric. Moreover, also the average link duration can be longer in comparison with PERRA and E-GPSR due to the capability to better discriminate the node behaviour associated not only with the current node condition but also with the history of link lifetime.

The proposed selfish node detection method and novel replica allocation techniques handle the selfish replica allocation appropriately. The proposed strategies are inspired by the real-world observations in economics in terms of credit risk and in human friendship management in terms of choosing one's friends completely at one's own discretion. We applied the notion of credit risk from economics to detect selfish nodes. Every node in a MANET calculates credit risk information on other connected nodes individually to measure the degree of selfishness. Further we plan to identify and handle false alarms in selfish replica allocation.

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