Performance Comparison Study of Routing Protocols for Mobile Grid Environment

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Summary

Integration of mobile wireless consumer devices into the Grid initially seems unlikely due to limitation such as CPU performance, small secondary storage, heightened battery consumption sensitivity and unreliable low-bandwidth communication. The current grid architecture and algorithm also do not take into account the mobile computing environment since mobile devices have not been seriously considered as valid computing resources or interfaces in grid communities. This paper presents the results of simulation done in identifying suitable ad hoc routing protocol that can be used for the target mobile grid application. The simulation comparing three ad hoc routing protocols named DSDV, DSR and AODV.

Key words:
mobile grid, ad hoc routing protocols, NS-2

1. Introduction

Most Grid applications have been in the area of Scientific Application where it involves numeric simulation and analysis of large data and complex problems. Integration of mobile wireless consumer devices into the Grid initially seems unlikely. However it is natural idea to extend the Grid's resource model to wireless mobile environment and potentially gain benefits from it. Although there will be a lot of questions will arise when mobility is incorporated into Grid, integration of them is beneficial.

Mobile networks can be classified into two classes: nomadic network and ad hoc network [20]. In this paper, we focus on the ad hoc networks. In an ad hoc network, the participants are used to route communication traffic from senders to receivers. Every participating node in these networks executes a routing algorithm that allows messages to be directed towards the next node along a route to the receiver. Protocols that support communication in ad hoc networks have to take into account the mobility of the participants and the variation in the connectivity between associated parties. All nodes behave as routers and take part in discovery and maintenance of routes to other nodes in the network. The objective of this paper is to carry out a performance study of three routing protocols that have been proposed for ad hoc networks that can be use for the target mobile grid application and other application which have the same parameters and scenarios.

The target mobile grid application that will be use as our case study in this paper is Forest Fire Fighter system (FFFS). This paper is organized as follows: Section 2 gives an overview of the scenario for the targeted mobile grid application. In Section 3, we describe the description of ad hoc routing protocol that used in this study. Section 4 describes the simulation environment that used for the study. In Section 5, we present the results from our study on selected ad hoc routing protocol. Section 6 describes the other related work on routing. Finally we present a brief conclusion and future work in Section 7.

2. The Targeted System Scenario

In public services, handling forest fire during drought season is very challenging task for the firemen when the area that involved in fire are very large. In most scenarios, the firemen that equipped with mobile devices are sent out to different locations of the fire spot. The data of the fire are reported through wireless connection to some control center for the operation management. These data organized and fed into a simulation program, which takes the current fire input and history information from some database and runs on mobile devices. Since mobile devices have limited local resources such as processing power, it needs to search for other resources (processing power) offered

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from other mobile devices in the area to process the data. After the mobile devices finished processing the given task, the result should then be sent back to the original sender. The simulation result will give forecast of the fire spreading in which the firemen can learn and take necessary prevention action from it. In this scenario, the application infrastructure will have two parts: a static part and a mobile part. This whole scenario requires communication of the application with mobile device and also communication between the mobile devices with other mobile devices through wireless mobile networks. The focus of this paper will be on the mobile part that is what is the best ad hoc routing protocol that can be used to route the instructions of the forest fire simulation system to other mobile devices to be process and vice versa.

3. Description of The Protocols

In this section, we briefly describe the key features of DSDV, DSR and AODV protocols that being studied in this paper.

3.1 Destination-Sequenced Distance Vector (DSDV)

DSDV is a distance vector routing protocol. Each node has a routing table that indicates for each destination, which is the next hop and number of hops to the destination. Each node periodically broadcasts routing updates. A sequence number is used to tag each route. It shows the freshness of the route. A route with higher sequence number is more favorable. In addition, between two routes with the same sequence number, the ones with less hops is more favorable. If a node detects that a route to a destination has broken, then its hop number is set to infinity and its sequence number updated (increased) but assigned an odd number. Even numbers correspond to sequence numbers of connected paths [1].

3.2 Dynamic Source Routing (DSR)

DSR is works on demand, without any periodic updates. The protocol is composed of route discovery and route maintenance. At route discovery, a source requesting to send a packet to a destination broadcasts a ROUTE REQUEST packet. Nodes receiving ROUTE REQUEST search in their route cache for a route to the destination. If a route is not found then the ROUTE REQUEST is further transmitted and the node adds its own address to the recorded hop sequence. This continues until the destination or a node with a route to the destination is reached. DSR also checks the route cache of the replying node and if a route is found, it is used instead.

At route maintenance, when originating or forwarding a packet using a source route, each node transmitting the packet is responsible for confirming that data can flow over the link from that node to the next hop. Acknowledgements are often already part of the MAC protocol in use (such as the link-layer acknowledgement frame defined by IEEE 802.11) or are passive acknowledgement. Passive acknowledgement means that a node knows that an intermediate node receives its packet since it can hear that the intermediate node further forwards it. If such acknowledgement is not available then a node can request an acknowledgement (which can be sent directly to the source using another route). Acknowledgements may be requested several times (until some given bound) and in the persistent absence of acknowledgement, the route is removed from the route cache and return a ROUTE ERROR to each node that has sent a packet routed over the link. Nodes overhearing or forwarding packets should make use all carried routing information to update its own route packet [1].

3.3 Ad Hoc On-Demand Distance Vector (AODV)

AODV is a distance vector type routing. It does not require nodes to maintain routes to destination that are not actively used. As long as the endpoints of a communication connection have valid routes to each other, AODV does not play a role. Same as DSR, the protocol is also composed of route discovery and route maintenance. The protocol uses different messages to discover and maintain links such as ROUTE REQUEST, ROUTE REPLY and ROUTE ERROR. These message types are received via UDP, and normal IP header processing applies.

AODV uses a destination sequence number for each route entry. The destination sequence number is created by the destination for any route information it sends to requesting nodes. Using destination sequence numbers ensures loop freedom and allows knowing which of several routes is fresher. Given the choice between two routes to a destination, a requesting node always selects the one with the greatest sequence number. When a node wants to find a route to another one, it broadcast a ROUTE REQUEST to all nodes in the network until either the destination is reached or another node is found with a fresh enough route to the destination. Fresh enough route is a valid route entry for the destination whose associated sequence number is at least as great as that contained in the ROUTE REQUEST. Then a ROUTE REPLY is sent back to the source and the discovered route is made available.

For route maintenance, nodes that are part of an active route may offer connectivity information by broadcasting periodically local Hello messages (special ROUTE REPLY message) to its immediate neighbors. If Hello messages stop arriving from a neighbor beyond some given time threshold, the connection is assumed to be lost. When a node detects that a route to a neighbor node is not valid it removes the routing entry and sends a ROUTE ERROR message to neighbors that are active and use the route. This is possible by maintaining active neighbors lists. This procedure is repeated at nodes that receive ROUTE ERROR messages. A source that receives a ROUTE ERROR can reinitiate a ROUTE REQUEST message [1].

4. Simulation Environment

Simulation is chosen as the technique for the performance evaluation due to time and cost constraint, more details can be incorporate and less assumptions is required compared to analytical modeling. Network Simulator Version 2 (NS-2) was used in this paper because it provides substantial support for simulation of TCP, UDP, routing and multicast protocols over wired and wireless networks [17][18][19]. The simulation model is based on multihop wireless networks with physical, data link and medium access control (MAC) layer which is modeled in NS-2. We use similar traffic and mobility models used by [2][6][7][21]. We use traffic-pattern and node-movement files available in the NS-2 for the simulation.

The grid application studied deals with continuous bit rate (CBR) traffic sources. The source-destination pairs are spread randomly over the network. Only 512-byte data packets are used. The mobility model uses the random waypoint model in 1500m x 300m field with 70 nodes. Each packet starts its journey from a random location to a random destination with a randomly chosen speed, which is uniformly distributed between 0 to 20 m/s. Once the destination is reached, another random destination is targeted after a pause. We vary the pause time (0, 50, 100, 150, 300, 600 and 900 seconds), which affects the relative speeds of the mobile nodes. Simulations are run for 900 seconds of simulated time for 70 nodes. Identical mobility and traffic scenarios are used across protocols.

4.1 Traffic Models

Random traffic connections of CBR can be setup between wireless mobile nodes using a traffic-scenario generator script. In this thesis we generate three traffic models for the 70 nodes which is maximum connections of 20 nodes with 4 packets/s, 50 nodes with 3 packets/s and 70 nodes with 3 packets/s and 2 packets/s respectively. We use slower rate with 50 and 70 nodes to avoid high network congestion for a meaningful comparison.

4.2 Mobility Models

The mobile nodes movement can be setup by using node-movement generator which is available in NS2. In this thesis we generate seven mobility models for the simulations with pause time of 0, 50, 100, 150, 300, 600 and 900 seconds.

5. Simulation Results

In this section, we present and compare the two performance metrics utilized in the simulation, which are packet delivery fraction and normalized routing load. Packet delivery fraction is the ratio of the data packets delivered to the destinations. It evaluates best-effort traffic. Normalized routing load is the number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission. This performance metric evaluates the efficiency of the routing protocol.

5.1 Packet Delivery Fractions

Figure 4.1(a),(b) and (c) shows packet delivery fractions for 20, 50 and 70 sources respectively. Overall with 20 sources, for packet delivery fractions, AODV outperforms DSDV and DSR. With 50 sources AODV and DSDV seem to compete with each other in where both protocols outperforms between each other at low pause times (high mobility) and high pause times (low mobility). However the difference of the packet delivery fractions is in small percentage only. For 70 sources, we implement two different rates that are 3 packets/s and 2 packets/s. However, we realize that with 3 packets/s the network start to congest. Thus, we stop analyze on 70 sources rate of 3 packets/s because it will not give meaningful comparison. We then concentrate on 70 sources rate of 2 packets/s as shown in Figure 4.1(c).

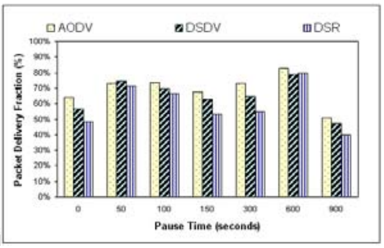

Fig. 4.1(a): Packet delivery fractions with 20 sources

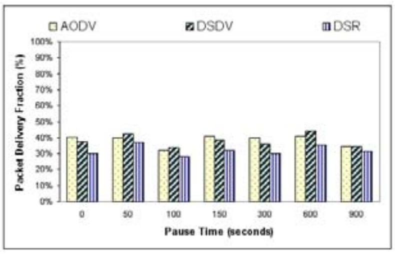

Fig. 4.1(b): Packet delivery fractions with 50 sources

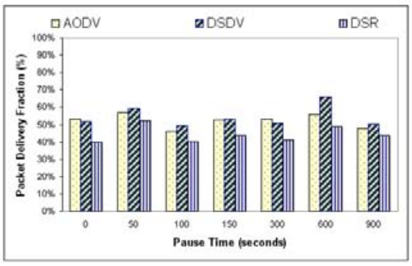

Fig. 4.1(c): Packet delivery fractions with 70 sources

With 70 sources rate of 2 packets/s, the packet delivery fraction offered is higher than the packet delivery fraction of 50 sources but lower than 20's sources. However non of the protocols success in delivering at least 80% of the data packets. The highest is only 66%. In most cases only around 50% of the data packet is sent. We can conclude that, when number of sources is increased, packet delivery fraction will become lesser.

In this section, we give explanation regarding the results. We choose three point of pause times which are 0, 150 and 900 seconds. At pause time 0 seconds (high mobility) environment, AODV outperforms DSDV and DSR. This is because in high mobility environment, topology change rapidly and AODV can adapt to the changes quickly since it only maintain one route that is actively used. DSDV deliver less data packet compare to AODV because in rapid change topology it is not as adaptive to route changes in updating its table. Since it only maintains one route per destination, data packet unable to be delivered since they are forwarded over a broken link and there are no alternate routes. Where as for DSR, it will search in their route cache for alternate route to the destination. Since DSR does not have mechanism in knowing which route in the cache is stale, data packet is forwarded to broken link. This shows that comparatively in high mobility, AODV performs better than DSDV and DSR regardless number of nodes.

When the pause time is 150 seconds (moderate mobility), AODV outperforms DSDV and DSR when the number of sources is small. When the number of sources began to increase, AODV and DSDV seem to have same performance. At pause time 900 seconds (low mobility) environment, AODV outperforms DSDV when the number of sources is low. When number of sources is high, DSDV start to outperforms AODV because when the topology does not change frequently, DSDV can directly used the routes information in the table. Thus we can say that both AODV and DSDV are appropriate for a low mobility network.

5.2 Normalized Routing Load

Figure 4.2(a),(b) and (c) shows normalized routing load for 20, 50 and 70 sources respectively.

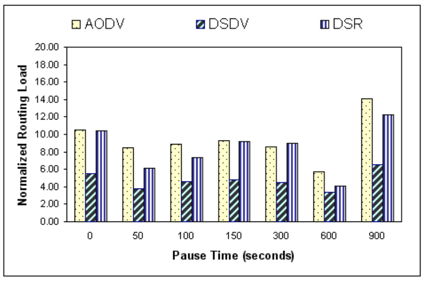

Fig. 4.2(c): Normalized routing load with 20 sources

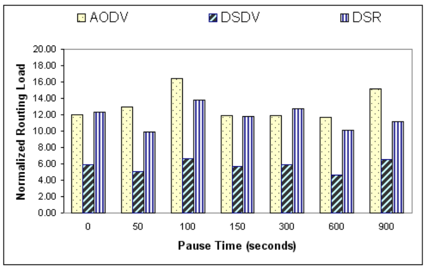

Fig. 4.2(b): Normalized routing load with 50 sources

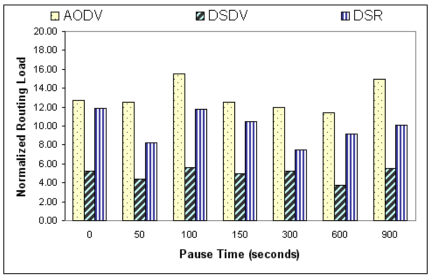

Fig. 4.2(c): Normalized routing load with 70 sources

In all cases (20,50 and 70 sources), DSDV demonstrates significantly the lowest routing load, follows by DSR and AODV.In high and moderate mobility environment, when the number of sources is low, AODV and DSR seem to have same routing load. However with large number of sources, DSR start to have lesser routing load compare to AODV. The major contribution to AODV's routing load overhead is from ROUTE REQUEST. AODV has more ROUTE REQUEST than DSR. This is because DSR has access to a significantly greater amount of routing information than AODV. For example, in DSR using a single request-reply cycle, the source can learn routes to each intermediate node on the route.

In low mobility, AODV always demonstrates higher routing load follows by DSR and DSDV. This is because AODV route learning is limited only to the source of any routing packets being forwarded. Thus AODV have to rely on route discovery flood more often, which may carry significant network overhead. While on the other hand, ROUTE REPLY constitutes a large fraction of DSR's routing overhead. DSDV always demonstrates the lowest routing load between the three protocols, because it is not as adaptive as AODV and DSR in maintaining routing information. Even though the routing load is the lowest, the packet delivery fraction provide by DSDV is less than AODV's for 20 sources but different in only 2% to 7% only. However the difference between packet delivery fractions provides by DSR is less than AODV's for around 2%-18%. This shows with small no of sources and less mobility, DSDV performs better than AODV and DSR.

6. Related Works

Several related works on performance comparison of ad hoc routing protocols had been studied in by [2][6][21]. The goal of the studies is basically to carry out a systematic performance study of ad hoc routing protocols for mobile ad hoc networks. In following sections we discuss several related works on routing protocol for use in grid computing.

6.1 Energy Efficient Cell Relay (EECR) Routing Protocol

Du in [4] proposed a new energy-efficient routing protocol for dense mobile ad hoc networks called Energy Efficient Cell Relay (EECR) routing protocol for dense mobile ad hoc networks. It is called cell relay routing protocol because the main idea is to use cells in the direction from source to destination to relay the packet. The entire routing area is divided into several equal-size small squares -- cells. In the study, node location information is used to simplify routing strategy. Only a small number of nodes are involved in one routing. This reduces the routing overhead and saves energy for other nodes. An extensive simulation is conducted to study the performance of the routing protocol, and compare the performance with well-known location based routing algorithms Location-Aided Routing (LAR) protocol. The simulation results demonstrate that the routing protocol has very good performance and good scalability. Both the computation and simulation show that the routing protocol incurs only about 25% of the routing overhead of LAR routing protocol.

6.2 Energy-Conserving GRID (ECGRID) Routing Protocol

Chao et al. in [3] proposed a routing protocol called Energy-Conserving GRID (ECGRID). Every mobile host in the network must run ECGRID. In ECGRID, the routing table is established in a grid-by-grid manner, instead of in a host-by-host manner. Therefore, only the gateway is needed to maintain the routing table. ECGRID is an extension of Location-Aware Routing Protocol for Mobile Ad Hoc Network (GRID - which is modified from AODV protocol) by considering energy conservation. In GRID, each mobile host has a positioning device such as a Global Positioning System (GPS) receiver to collect its current position. The geographic area of the entire MANET is partitioned into 2D logical grid. Routing is performed in a grid-by-grid manner. One mobile host will be elected as the gateway for each grid. This gateway is responsible for (1) forwarding route discovery requests to neighboring grids, (2) propagating data packets to neighboring grids, and (3) maintaining routes for each entry and exit of a host in the grid. No non-gateway hosts are responsible for these jobs unless they are sources/destinations of the packets. In ECGRID, grid partitioning is the same as in the GRID routing protocol. The main difference between these two protocols is that ECGRID considers the energy of mobile hosts but the GRID does not. For each grid, one mobile host will be elected as the gateway and others can go into sleep mode. The gateway host is responsible for forwarding routing information and propagating data packets as in GRID. Sleeping non-gateway hosts will return to active mode by the signaling of the gateway, whenever data have been sent to them. Simulation results demonstrate that ECGRID can not only prolong the lifetime of the entire network but also maintain good packet delivery ratio. A host runs ECGRID consumes less energy than a host runs GRID does. Additionally, the lifetime is extended in proportion to the host density in the whole network.

6.3 Routing and Resource Discovery in Phoenix Grid-Enabled Message Passing Library

Kaneda et al. in [11] proposed a communication subsystem of a "Grid-enabled" message passing library, in the context of Phoenix message passing model. It supports:

- message routing between nodes not directly reachable due to firewalls and/or Network Address Translation (NAT);
- resource discovery facilitating ease of configuration that allows nodes without static names (e.g. DHCP nodes) to participate in computation without specific efforts; and
- nodes dynamically joining/leaving computation at runtime.

It is argue that in future Grid environments, all of the above functions, not just routing across firewalls, will become important issues of Grid-enabled message passing systems including MPI. It is also argue that unlike solutions commonly proposed by previous work on a Grid-enabled MPI, the suggested system runs a distributed resource discovery and routing table construction algorithm, rather than assuming all such pieces of information are available in a static configuration file or alike.

The proposed algorithm consists of routing table construction and resource discovery. The basic ideas is get from a body of work on routing and resource discovery. The routing table construction algorithm is based on the Destination Sequenced Distance Vector (DSDV) routing algorithm, originally proposed in the context of mobile ad-hoc network routing. It gives the researchers a good starting point because it adapts to changes of the connection topology and consumes a relatively small amount of memory compared to other schemes based on distance vector. In DSDV, each routing table, at each node, lists all available destinations.

For resource discovery algorithm, each node needs to discover available machines that it does not know in the beginning. Each node needs to collect information about available machines by exchanging messages with other nodes. Experiment results using 400 nodes in three LANs indicate that the algorithm is able to dynamically discover participating peers, connect them each other and calculate a routing table.

7. Conclusion and Future Work

We have implemented simulation of ad hoc network routing protocols, which involve DSDV, DSR and AODV. We used parameter, which is suitable with the application parameters. Simulation results show that when number of nodes participating in the network is increased, packet delivery fraction of data packet delivered by all the protocols will become lesser. Through the simulation result, we can conclude that in most cases that AODV performs better than DSDV and DSR regardless of mobility rate.

Mobile part of forest fire grid application will not involve too much mobility. However number of nodes participating the related network might be varies from small to larger amount. Since one of necessary characteristics of grid computing is scalability, which means a grid should operate equally well with small and large participant, AODV is proposed to be used in the application. However, we need to study further on the delay of the packet delivery since the application must responds to the information fed in by the firemen into the application quickly. The quick result from the application is necessary in forecasting the fire spreading and taking prevention action.

In this paper, we mainly target the performance comparison based on packet delivery fraction and normalized routing load. In the future, extensive complex simulations could be carried out in gain a more in-depth performance analysis of the ad hoc routing protocols. This would include delay of data packet delivery and performance comparison on location-based ad hoc routing protocols.

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