

1 Papers for Reading: Virtual Mobile Nodes

Dolev, S., Gilbert, S., Lynch, N., Schiller, E., A. Shvartsman, A., and Welch, J. Virtual Mobile Nodes for Mobile ad hoc Networks .18th International Symposium on Distributed Computing (DISC04), Trippenhuis, Amsterdam, the Netherlands, October 4-7, 2004, volume 3274 of Lecture Notes in Computer Science, pp: 230-244, Springer-Verlag, December 2004.

2 Introduction and Challenges

In wireless network, where the motion of the nodes are not static and nodes are allowed to move the algorithm applicable for static network becomes more complex. The motion of the mobile nodes in such a network is not predictable; that is the mobile nodes travel wherever they want to go. Perhaps, this means the motion of the mobile nodes are not known or preloaded. The reliability nature of the mobile nodes are not guaranteed; The nodes may fail due to battery drainage, or the node might go to sleep or turns the power off to save energy. Thus the communication path can't be guaranteed. Since the nodes operate on battery, the communication becomes highly expensive if the transmission range of the nodes are increased. Thus, the communication locality is restricted to nearby neighboring nodes. Global communication becomes highly expensive. Further more, the nodes have small amount of memory and are not loaded with powerful processor to compute big operation. Perhaps bigger computation consumes higher energy, henceforth the computationally the nodes are also limited. Overall, the nodes are limited by communication, storage, computation and battery energy.

3 Opportunities from Wireless Network

Although, the above mentioned limitations exists, there are few important features of the nodes which can be exploited. It is possible to maintain highly synchronized clocks, using the combination of GPS, clock synchronization algorithm and other techniques proposed in the literature (perhaps this is a very strong assumption made in this paper). Since the nodes can be equipped with GPS systems, it is feasible to obtain the node's current location as they move around. Also they have access to their current location. The basic feature of the wireless network is broadcast. When a node transmits any message, all the neighboring nodes in the

transmission range can hear to it. Thus the wireless broadcast is a powerful primitive. It allows a node to reach all the nearby nodes and ensure that they receive the same message.

4 System Model and Assumption

4.1 Mobility

The nodes in the network are assumed to be highly dynamic. For simplicity the nodes are assumed to travel in 2D plane on a continuous path. This assumption can easily be waived, and this doesn't limit the extension of the proposal as such. The speed at which the nodes move though are not preloaded or predefined, it is just limited to be $\leq v_{max}$. Also the nodes are allowed to join, leave, and crash any point of time. Basically, each node has unique identifiers.

4.2 Geographic Information

Each node is equipped with GPS or devices that can provide the node location information and time information exactly. Thus the nodes are assumed to be time synchronized all the time, and can obtain its location information wherever it moves to.

4.3 Communication

The nodes when they transmit the message, it arrives every node within the distance $\leq R$, and the message arrives in time $\leq d$. This is local broadcast capability. This means that there exists some collision algorithm that resolves the conflicts and delivers the messages within d delay. If the range R is considered small enough, and using a backoff protocol to ensure d , this becomes a feasible assumption.

5 related work

Compulsory protocol is illustrated as follows: if the mobile nodes were reliable and their motions are predictable, the task of designing algorithm can be significantly simplified for mobile network. The nodes moving in a programmable way, can be utilized to take advantage, performing even more efficiently than in static network. The protocol requires only a subset of mobile nodes to move in a pre-specified manner. Perhaps, to waive such restriction over movement and achieve the same efficiency is the goal of the paper.

Agent based algorithms are one in which the process jumps from one physical node to another nodes as the nodes move. This is a very good method achieving the goal, however it doesn't guarantee reliability. It is not fault tolerant. There are geographic algorithms like, Focal point abstraction, in which static atomic objects are assumed to exist in the middle of mobile nodes. Persistent node abstraction proposes mobile virtual entity around static network, Nath, et. al

proposes method for forwarding messages in a precalculated paths, Geocast methods route data geographically. Most of the methods focuses mainly on determining good trajectories, which is not the goal of this paper. These paper doesn't address several issues like fault tolerant, complete mobility, etc.

6 Basic System Model - Virtual Mobile Nodes

The paper proposes an executing algorithm on both virtual mobile nodes (VMN) which are abstract nodes moving in predefined predictable manner, real mobile nodes(RMN) which moves in an unpredictable manner. Motions of VMN are preloaded in RMN. There exists no correlation between the motions of VMN and RMN. For instance, the VMN can move in opposite direction as of RMN. The requirement this algorithm poses is that VMN should move in dense area for no failure of VMN in order to guarantee recovery. Perhaps, even in case of holes, the recovery is possible once the VMN comes to dense area. Mobile Point Emulator (MPE) emulates VMN, by making RMN near VMN location assist in emulating VMN. Robustness of the VMN state is achieved by replicating at multiple VMN.

The VMN moves in a predictable pattern, where as the VMN is a program consist of local state (value, message, etc), code fro execution of aggregation operation, fixed path of travel. VMN is a combination of compulsory protocol, agent system, geographic algorithm with replication. Reliability of the nodes are guaranteed by replication, recovery. The VMN' are allowed to communicate with all the nearby RMN's within the distance of $\leq R_{virt}$, perhaps other VMN's. They are capable of repeating, reordering messages on the path.

6.1 Application of VMNs

The idea of VMN are useful in routing messages. This can be considered as a public transport system, which people use. If a message(people) arrives at a particular instance VMN(bus) is present at that particular locality and instance, it can be routed or carried over. Perhaps, the latency and space usage scale with the number of VMN's and region size and not with number of RMN. This is obvious in the sense, that the storage space requirement increases to store the program of VMN in RMN as the number of VMN increases. Further, if there are more number of VMN, then the latency for formation and routing of messages increases due to TOB (discussed later), and replication.

The VMN can be efficiently ustilized to aggregate, collect, and process the sensor data. Perhaps, the group communication can be easily ensured without the need of ticket for the messages to be routed among the group members. REal world applications can be enlisted as below,

1. monitoring zebras
2. tracking zebras

3. collecting information on zebra behavior
4. studying zebra migration patterns

7 VMN Implementation

7.1 Simple Agent Based Implementation

As we discussed before, if the VMN are assumed to perform as like agents; the process migrates or jump from one RMN to another in the pre-defined path. This methodology works well as long as there are no failure of nodes in the path. In case of failure of even one node the state is lost even in dense area. A modified robust implementation is MPE.

7.2 Mobile Point Emulator

In this methodology, instead of having one node, the data is replicated at every mobile nodes within a radius of R_{MP} of the VMN. This uses replicated state approach, where as this assures all the nodes in the circular range maintains the state. This eliminates single point of failure. Thus as far as there are nodes in the radius, the state is maintained. However this incurs heavy communication overhead. It has always been a trade off between overhead and robustness.

The VMN are capable of receiving message from RMN, for instance a sensor node sends a message to VMN saying the "current temperature is 50 degrees". Perhaps on receipt of a message, it get replicated among all the replicas in the radius. This maintains consistency. The VMN are capable of sending messages to RMN, for instance it may send query "what is the temperature". The VMN are capable of performing computations like aggregation for instance SUM, AVG, etc.

7.2.1 Joining and leaving a VMN

It is simpler for any node to join and leave a VMN as the node moves in and out of VMN radius. When a node comes in the range of a VMN, then it request to join the VMN. It listens to action messages, and other members in VMN gives join acceptance. Once it receives the acceptance it performs all the actions messages. New nodes listen for updates, and becomes active. When a node fails, nothing have to be done. When a nodes leaves the VMN, it just need to clear the state.

7.2.2 Failure and recovery of Nodes

It is possible when VMN moves to unoccupied area, where no RMN are available. Thus the VMN fails and loses the state information. When the VMN moves to occupied area, the new node try to join. When it infers no messages, then it resets the state and becomes the member of the VMN.

7.2.3 Maintaining Consistency - Message Total Ordering

It is high likely possible that two replica's in same VMN may have different messages for a temperature, due to time delay for messages. To avoid this nodes process messages in the same order. Each messages are uniquely timestamped. The messages are broadcasted, and rebroadcasted with a delay of d , and delivered with timestamp. Assuming that $R \geq 2R_{virt} + dv_{max}$, if a node in a MP sends a message, then all other active nodes in MP receives it in same order.

8 Discussion and conclusion

Due to the mobility of the nodes in the mobile network, it becomes harder to develop algorithm. Virtual mobile Nodes are predictable and reliable. This paper proposes an algorithm and a framework to implement VMN, on top of which any other algorithm for mobile ad hoc network can easily be developed. This provides a reliable infrastructure for the mobile network.

However, there are few drawbacks in the framework as such. This relies completely on timely communication and reliable services. No untrusted environment is assumed, where nodes might act malious. It becomes difficult to extend this framework. The replication is highly expensive in terms of communication and power as such. These leads to several research challenges, like optimized implementation by minimizing messages when membership is stable. To tolerate unreliability and untimely communication services with more dynamicVMN where the path of VMNs are determined route-on-the-fly way and generate new VMNs dynamically.