International Journal of Wireless Networks and Communications.
ISSN 0975-6507 Volume 6, Number 1 (2014), pp. 1-8

http://www.irphouse.com

Distributed Algorithm for Topology Control in Heterogeneous Ad-hoc Networks

G. Anandhi and Dr. S. K. Srivatsa

Research Scholar, Vels University, Chennai – 117
Senior Professor, St. Joseph's College of Engg, Chennai-117
Email: giri_anandhi@hotmail. com, profsks@rediffmail. com

Abstract

A mobile ad hoc network is a collection of wireless terminals that can be deployed rapidly. Its deficiencies include limited wireless bandwidth efficiency, low throughput, large delays, and weak security. Integrating it with a well established cellular network can improve communication and security in ad hoc networks, as well as enrich the cellular services. The integration of heterogeneous wireless technologies can improve the network performance, thereby meeting the demands for different quality of service (QoS). Power heterogeneous ad hoc networks are characterized by link layer asymmetry: the ability of lower power nodes to receive transmissions from higher power nodes but not vice versa. Normally flooding occurs in Heteregeneous Networks. In this paper, we propose On demand Utility-Based Routing Protocol (OUBRP), which is designed to improve the efficiency of on-demand routing protocols under a Heterogeneous networking environment.

Topology control in an ad-hoc network can provide better spatial reuse of the wireless channel and conserve power. Topology construction and maintenance is a challenging issue. A number of distributed topology control algorithms have been proposed to remove the need of a centralised controller. Distributed algorithms such as location information no topology (LINT), location information link state topology (LILT) and mobile-grid (MG), aim to achieve overall network connectivity and low transmission range by maintaining a minimum node degree value. In the case of a non-uniform node distribution, maintaining a minimum node degree can unnecessarily partition a network. In this paper, we propose a distributed algorithm that utilises one hop neighbours and their location information to maintain a number of critical links required to keep a connected network. Such critical links are included along with the links required to meet the node degree criterion. A distributed mechanism to construct and maintain a network topology is proposed, which can be integrated as part of the neighbour discovery protocol. Furthermore, nodes collaborate to remove unidirectional links. A simulation based analysts of the proposed algorithm is provided for a number of node degree values. Simulations indicate that the proposed algorithm is able to achieve higher connectivity for different node distributions.

Keywords: WLAN, CAMA (Cellular Aided Mobile Ad hoc Network)

Introduction

As ad hoc networks gain popularity, one might expect emerging networks to consist of multifarious devices with differing capabilities. One could envision low power sensor nodes, wireless hand-held devices, laptops and bigger and more powerful wireless devices housed in vehicles, all integrated into a single network. In such a heterogeneous network, different nodes are likely to have different power capabilities and thus, are likely to transmit with different power levels. This, in turn, leads to possible link asymmetry wherein the transmission of a high power node is received (or is sensed) by a lower power node whereas the high power node cannot sense the transmissions by the low power node. The effects of asymmetry also pose challenges when power control is to be employed in ad hoc networks. In the presence of such asymmetry, traditional protocols that are typically designed with an implicit assumption that links are bi-directional, either fail or perform poorly. Specifically, at the MAC layer, this leads to an exacerbation of the hidden terminal problem. Routing becomes more complex due to the presence of such unidirectional links.

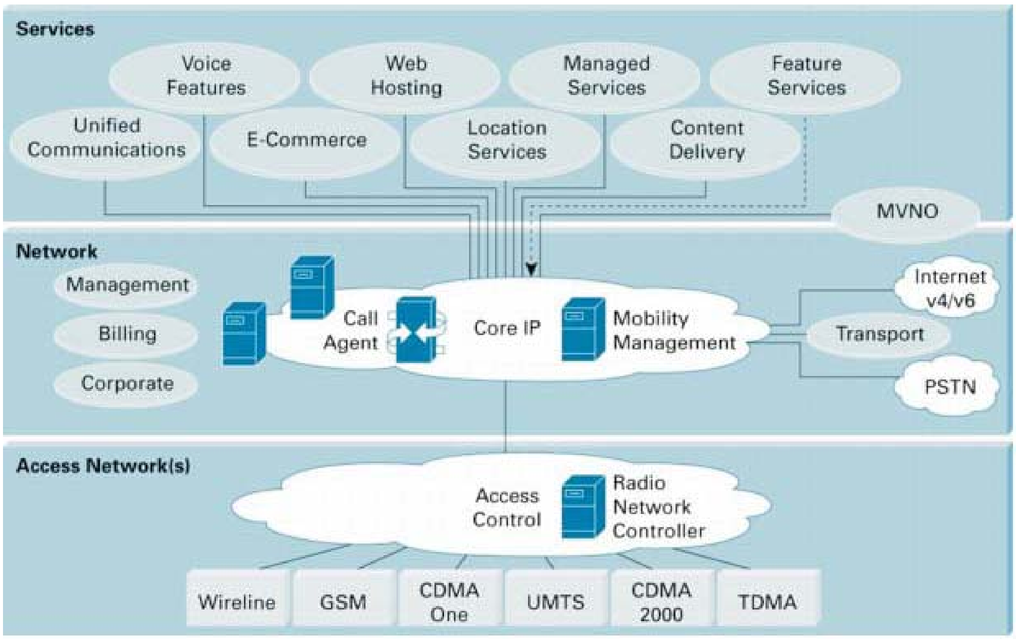

Figure 1: Integration of different Wireless Access Networks

Integrate different layer two devices into one single mobile adhoc network, with respect to

– Transparency: Transparent end-to-end communication
– Mobility: Common mobility scheme
– Addressing: Interface independent addressing
– Configuration: Ad Hoc configuration
– End-to-end communication abstraction that supports MAC-switching, node mobility and multi-homing

CAMA (Cellular Aided Mobile Ad hoc Network) can improve the ad hoc network in:[3]

_ Synchronization The clock for all ad hoc users can be adjusted according to that of the cellular network in one step.
_ Authentication In CAMA, MTs can go through the same authentication procedure as in cellular networks. The MTs can also be authenticated by special MTs, which can be reached easily by an entrant MT through the cellular radio channel.
_ Power saving The transmitting power of MTs can be estimated since the distance between any two MTs is known. Additionally, in any new route discovery, the intermediate MTs need not receive and forward routing packets.
_ Radio resource allocation The centralized CAMA agent can guide MTs to access the proper ad hoc channels in networks which have more than one ad hoc channel.
_ Broadcasting and multi-casting Data can be sent to the base station (BS), and broadcast or multicast through the cellular radio channel. No further data forwarding is needed.
_ Finding cluster head in clustered ad hoc routing In clustered ad hoc routing, the CAMA agent can determine the cluster heads since it has the information of MTs, e. g., positions, stability, and power. On the other hand, clustered routing may improve CAMA. The CAMA agent has to communicate only with cluster heads, thus reducing the load in the cellular network.

Heterogeneity in Mobile Devices

As shown in Figure 2 mobile devices can exist in many forms. There are great differences among these devices, and this heterogeneity can affect communication performance and the design of communication protocols.

The ability of an ad hoc mobile device to act as a server or service provider will depend on its computation, memory, storage, and battery life capacity. The presence of heterogeneity implies that some devices are more powerful than others, and some can be servers while others can only be clients. In addition, relaying packets for others can result in a device expelling its own energy. Hence, a mobile node should examine its own “well-being” before committing to forwarding packets on the behalf of others.

Figure 3 shows that despite the differences in ad hoc mobile devices, they can still be networked together wirelessly. The information and processing needs may not be the same, however. A palm pilot with a smaller display may not be capable of displaying large word processing-based applications. An active badge has a limited user interface for word processing. It acts more like a sensor and actuator rather than a user terminal.

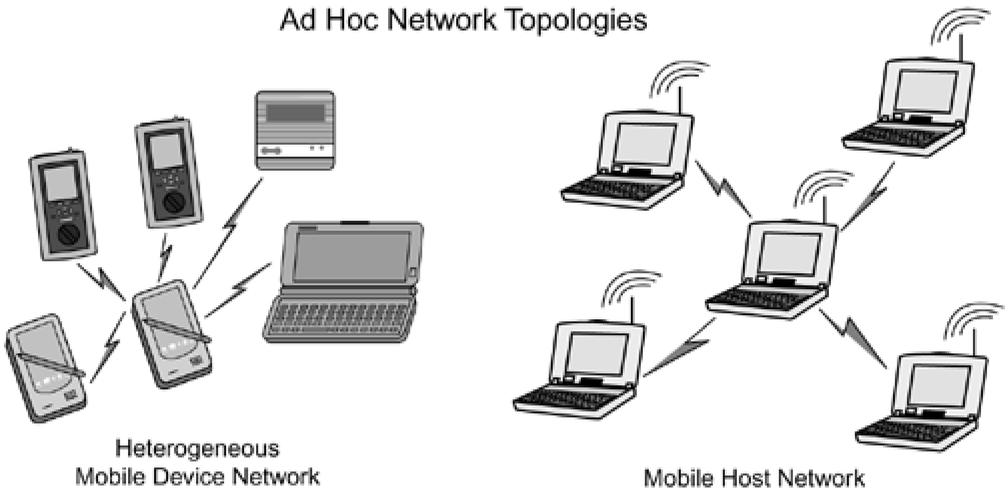

Figure 2: (a) Heterogeneous mobile device ad hoc networks, and (b) homogeneous ad hoc network comprising powerful laptop computers.

Heterogeneous mobile handheld devices (source: COMPAQ), and (b) an Active Badge (source: Olivetti Research)

Figure 3 Heterogeneous Integrated Wireless Networks

Heterogeneous integrated wireless networks have been widely applied and studied. Examples of application of integrated technology are AMPS/IS-95 cellular network, global positioning system GPS applied in cellular network to provide position services, and satellite/cellular network.

There is also a growing interest in the integration of cellular network and wireless LAN (WLAN). The Universal Mobile Telecommunication System (UMTS), also called the 3G cellular network, is able to provide different services (voice and data services) on its own. However, due to the limited radio bandwidth, the network cannot accommodate a large number of users simultaneously, especially for applications requiring fast data transmission rate. In addition, the service cost is high. As a supplement to the cellular network, WLAN may provide services with high transmission data rate at a relatively low cost. The integration of these two heterogeneous networks can provide better service by having mobile users handoff back and forth between the networks to get the desired services. However, WLAN has a very small radio coverage (especially in urban areas) and can only provide services to users very close to its fixed access points. To be able to serve most of the users in such an integrated network, a high density of WLAN access points have to be deployed. This leads to the increased cost and reduced efficiency of the fixed infrastructure. To overcome this drawback, an ad hoc network can be used instead of WLAN. In the ad hoc/cellular integrated network, multi-hop ad hoc links virtually extend the radio coverage. The mobile users outside the radio coverage of service access points (fixed or mobile) can also be accessed through intermediate forwarding. Peer-to-peer service can be achieved directly through the ad hoc network without going through the cellular network. Additionally, the ad hoc channels may be used to forward traffic between cells to get load balancing in the cellular network. This further improves the cellular network's capacity. These works focus on how ad hoc network may enhance cellular services. The approach may be called ad hoc aided cellular networks. [2]

General Simulation Model

The most recent version (2. 26) of the network simulator ns2 is used for the experimental study. We simulate an ad hoc network with 100 MTs residing in an area of 1000m_1000m. Each MT moves within the area, with a random direction and a random velocity uniformly distributed between 0 and a maximum value. Without any specification, this maximum value is 3m=s, the speed for pedestrian users. The ad hoc channel has a fixed data rate of 1Mb=s. The wireless interface works like the 914 MHz Lucent WaveLAN, with a nominal radio range of 250m. MSGPR (multi-selection greedy positioning routing) under CAMA environment is compared with two other ad hoc routing protocols, AODV and DSR. The searching set for MSGPR is set large enough so that the best route can always be found. We assume that position updates and routing requests can always be sent successfully to the CAMA agent at their first attempts. In this work, the case that MTs send their associations with neighboring MTs is not included. [4]

Proposed Strategy

In this section, we introduce On-demand Utility-Based Routing Protocol. In current routing protocols proposed for MANETs it is assumed that the network is made entirely of homogeneous nodes. In Heterogeneous networks there may exist varying types of devices with different capabilities.

OUBRP, takes into account the possible heterogeniality of MANETs and proposes a new strategy to efficiency use the available resources in these networks, while minimising the number of control packets transmitted into the network.

Route Discovery in OUBRP

OUBRP aims to reduce the number of rebroadcasting nodes in the network during the route discoverv phase. This is achieved through a utility-based route discovery algorithm, which selects the most resource rich nodes in the network. Route discovery is performed over a number of different iterations. In the first iteration the algorithm allows only the most resource rich (i. e. the nodes with the highest required utility level) nodes to re-broadcast during the route discovery phase. If the first iteration fails to determine a route to the required destination, then the source node reduces the utility level requirement (in calculated levels, after a route discovery failure) to allow less resource rich nodes to also participate in routing.

Uni-directional Link Elimination (ULE)

In a Heterogeneous routing environment where there are devices with different transmission capabilities (e. g. Transmission power), it is highly likely that many nodes may form unidirectional links. This can create problems during route discovery in on-demand protocols. For example, assume a node A with a high transmission power forwards a RREQ to another node B with lower transmission power, which has a route to the destination D. However, node A is not within node B's transmission range. In this case, the link reversal algorithms used in on-demand routing strategies such as AODV will fail. Furthermore, nodes may store inaccurate routing information in their routing table by assuming they have a reverse link to the sender (i. e. node B may assume that it has a link to node A and store this in its routing table). To solve this problem, we propose Uni-directional Link Elimination (ULE). In this section we describe a GPS-based strategy which addresses this problem, which we refer to as ULE-L (i. e. ULE using Location information). We also present a number of altemative strategies for ULE. In ULE-L, each node forwarding a RREQ stores its location information within the RREQ packet. The receiving node will then check to see if the forwarding nodes locution falls within its transmission range. If yes, it updates its route table (i. e. assuming bi-directionality) and rebroadcasts the RREQ packet, or sends back a RREP if a route to the destination is known. Otherwise, it deletes the RREQ packet. We also implement this strategy on the top of AODV and illustrate the performance gains and the impact of this strategy on the success of the route discovery phase in AODV.

ULE using Neighbour List Forwarding

Another way to eliminate the uni-directional link selection problem during the route discovery phase is by appending a neighbor list to the RREQ packets. We refer to this strategy as ULE using Neighbour List Forwarding (or ULE-NL). In this strategy, the nodes, which participate in route discovery append a list of their neighbouring nodes to the RREQ packet. The nodes which then receive the RREQ packet check the neighbour list forwarded by the previous node to see if the forwarding node has a direct link to them. If yes, the receiving nodes would assume that they have a bi-directional link with the forwarding node and update their route tables. The receiving nodes then send a RREP if they have a route to the destination or rebroadcast the RREQ packet and replace the forwarding nodes neighbour list with their own neighbour list. Otherwise, the RREQ is deleted, The advantage of ULE-NL over ULE-L is that ULE-NL does not rely upon a GPS device to detect uni-directional links. Furthermore, by providing a neighbour list the receiver can confirm bi-directionality if its address exists in the senders neighhour list. However, in ULE-L bi-directionality is assumed according to transmission range of the receiver and no confirmation is given by the sender (i. e. the sender has not confirmed a reverse link from the receiving node). The disadvantage of ULE-NL is than each RREQ packet may he significantly larger that the RREQ used by ULE-L. This is because in ULE-L nodes exchange location information rather than a neighbour list.

Conclusions

The work discusses the integration of various medium access schemes into a transparent heterogeneous mobile ad hoc networks. A solution based on a virtual layer two device was proposed, implemented and measured. The proposed solution is transparent to application and routing. It performs good in terms of throughput and handover time. For the case of a multi-link there is a trade-off between throughput and handover time. In this paper we presented a new routing strategy for Mobile Ad Hoc Networks, which are made up of heterogeneous devices. We proposed a utility-based routing strategy (called OUBRP), which attempts to minimise the nuinher of control packets disseminated into the network. Furthermore, we demonstrated the effects of uni-directional links on routing performance and data delivery and proposed a number of uni-directional link elimination strategies for on-demand routing protocols in mobile ad hoc networks. In the future, we plan to investigate the performance of OUBRP in large (both node density and network boundary) mobile networks with high levels of traffic.

References

[1] IEEE STD 802. 11 1999. Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, 1999.

[2] T. S. Rappaport, Wireless Communications: Principles and Practice, Prentice Hall, 2003.

[3] S. Ni, Y. Tseng, Y. Chen and J. Sheu, “The broadcast storm problem in a mobile ad hoc network”, ACM/IEEE MOBICOM 1999.

[4] NS2: Network Simulator. http://www. isi. edu/nsnam/ns/

[5] N. Poojary, S. V. Krishnamurthy and S. Dao, “Medium Access Control in a Network of Ad Hoc Nodes with Heterogeneous Transmit Power Capabilities”, Proceedings of ICC 2001.

[6] V. Shah, S. V. Krishnamurthy and N. Poojary, “Improving MAC Layer Performance in Ad Hoc Netowrks of Nodes with Heterogeneous Transmit Power Capabilities”, Proceedings of ICC 2004.

[7] E. Jung and N. H. Vaidya, “A Power Controlled MAC Protocol for Ad Hoc Networks”, ACM/IEEE MOBICOM 2002.

[8] J. Monks and V. Bharghavan, “A Power Controlled Multiple Access Protocol for Wireless Packet Networks”, IEEE INFOCOM 2001.
[9] E. Royer and C-K. Toh, “A Review of Current Routing Protocols for Ad hoc Wireless Networks”, IEEE Personal Communications Magazine, April 1999.
[10] J. Yoon, M. Liu and B. Noble, “Random Waypoint Considered Harmful”, IEEE INFOCOM, 2003.
[11] T. Saadawi and S. Xu, “Performance Evaluation of TCP Algorithms in Multi-hop Wireless Packet Networks”, Journal of Wireless Communications and Mobile Computing 2002.
[12] R. Ramanathan and R. Rosales-Hain, “Topology Control of multihop wireless networks using transmit power adjustment”, In the proceedings of IEEE INFOCOM, volume 2, pages 404-413, 2000.
[13] S. L. Wu, Y. C. Tseng and J. P. Sheu, “Intelligent medium access for mobile ad hoc networks with busy tones and power control”, IEEE Journal on Selected Areas in Communications, 18(9): 1647-1657, 2000.
[14] A. Muqattash and M. Krunz, “Power controlled dual channel (PCDC)Medium Access Protocol for Wireless Ad hoc networks”, In the proceedings of IEEE INFOCOM 2003.
[15] M. K. Marina and S. R. Das, “Routing performance in the Presence of Unidirectional Links in Multihop Wireless Networks”, ACM Mobihoc 2002.
[16] V. Ramasubramanian, R. Chandra and D. Mosse, “Providing Bidirectional Abstraction for Unidirectional Ad Hoc Networks”, In Proceedings of IEEE INFOCOM, June 2002.
[17] S. Nesargi and R. Prakash, “A Tunneling Approach to Routing with Unidirectional Links in Mobile AdHoc Networks”, In Proceedings of International Conference on Computer Communications and Networks (IC3N), pages 522-527, 2000.
[18] E. Duros, W. Dabbous, H. Izumiyama, N. Fujii and Y. Zhang, “A Link-Layer tunneling mechanism for Unidirectional links”, RFC 3077, 2001.
[19] L. Bao and J. J. Garcia-Luna-Aceves, “ Link-state Routing in Networks with Unidirectional Links”, In Proceedings of International Conference on Computer Communications and Networks (IC3N), pages 358–363, 1999.
[20] P. Sinha, S. V. Krishnamurthy and S. Dao, “Scalable Unidirectional Routing using ZRP extensions for Wireless Networks”, In Proceedings of IEEE WCNC, 2000.
[21] R. Prakash, “A Routing Algorithm for Wireless Ad Hoc Networks with Unidirectional Links”, ACM/Kluwer Wireless Networks, 7(6):617–625, 2001.
[22] R. Prakash, “Unidirectional Links Prove Costly in Wireless Ad Hoc Networks”, In Proceedings of the Worskshop on the Discrete Algorithms and Methods for Mobile Computing and Communication (DIALM’99), pages 15-22, August 1999.