Performance Evaluation of Hybrid Mesh Routing Protocol using Self-configuring Mechanism for Wireless Mesh Networks

H R Ranganatha[1], T G Basavaraju[2]
[1]Research Scholar, Jain University, Bangalore 560 027. INDIA
[2]Professor, Department of Computer Science and Engineering,
Government SKSJ Technological Institute, Bangalore 560 001. INDIA.

***Abstract*--Wireless Mesh Networks (WMN) has started a new trend delivering and supporting Internet Broadband access users. The wireless mesh network exhibits several issues with throughput, security and quality and most of them have been resolved successfully. Thus, there is a great demand and interest on architectures and IEEE standard 802.11s that has created lot of support for predominant mesh routing protocols for wireless mesh networks. In this paper, we evaluate scalable hybrid routing protocol self configuring itself for large scale Wireless Mesh Networks. The concept of agent technology is proposed for self-organizing mechanism for wireless networks based on popular hybrid mesh routing protocol for mesh networks. The incorporation of self organizing module the performance of the network in increased by varying the network size. It can be seen clearly that Self configuring HWMP outperforms when compare to HWMP in terms of throughput and delay when varied with network size and traffic loads.**

Keywords:Mesh Networks, Self-configuring, performance evaluation.

I. INTRODUCTION

Researchers have considered Wireless Mesh Networks (WMNs) as a key technology for them to work on next generation wireless networks. WMN is a mesh network which is implemented over a wireless network system with low cost, high scalability, reliable services and easy maintenance. Another direction or alternative for last-mile broadband Internet access which has greatest potential to play a critical role is Wireless Mesh Networks. These networks are considered as a special case of multi-hop mobile ad hoc networks where the nodes have fixed locations and communicate to the internet through one or more gateways. Mesh networks are grouped by dynamic self-organization, self-configuration and self-healing.

In case of wireless mobile environment, the routing functionality of network layer must be adopted to support dynamic topologies and link capacity and also mobile nodes in the network [1]. Routing needs to be adapted to a specific application and also it must match radio environment. Cross-layered design techniques have been proposed for wireless networks to improve the system performance [2, 3, 4] and security [5].

The present 802.11 based wireless networks completely depend on wired infrastructure to transfer the traffic to end users. This makes wired infrastructure expensive and inflexible for wireless local area networks (WLAN) as coverage cannot be extended beyond the back-haul deployment. The performance of a WMN is mainly dependent on the design of the routing protocols and also associate metric used to measure it. The main goal of any routing protocols is to select the best path between the source and destination based on the routing metric. Most of the existing protocols used in WMNs rely on the network layer (IP) and use hop count to allow multi-hop communication and do not provide an good solution for wireless networks. The new standard IEEE 802.11s was developed by IEEE task group to design and develop a scalable integrated mesh networking solution. Even though, this group set hybrid wireless mesh protocol (HWMP) [6] as default routing protocol, but still there exists scope for extending scalable routing protocol for WMN. In addition this, airtime [7] metric was considered as default routing metric. We design and develop a new scalable routing protocol called SHWMP (Scalable Hybrid Wireless Mesh Routing Protocol) and also new metric called TCET (Total Cumulative Expected Time) is suggested to measure the performance of scalable routing protocol. The airtime metric was only focus on consumption of resource by a packet on a link. This metric only cannot be used as standard, since there are so many parameters which mainly required measuring the overall performance of WMN.

The rest of the paper is organized as follows: In section II, related work carried out recently is discussed. Section III Self-Configuring model is discussed. Section IV discusses simulation environment and the simulation results are analyzed and discussed in Section V. The conclusion is drawn in Section VI.

II. RELATED WORK

There are several research works carried out to evaluate the performance of routing protocols such as Ad Hoc On Demand Distance Vector (AODV) [8] and Optimized Link State Routing Protocol (OLSR) [9], which are based on on-demand and table-driven forwarding technique, respectively.

Many researchers in past years have compared the routing protocols considering a standard wireless ad hoc network [10], [11], [12], [13]. The traditional ad hoc networks differ from wireless mesh networks in having only Mesh Points (MPs) which are connected in ad hoc fashion. The STAs can move from one AP to another and consider it as infrastructure network. In name portals, few MPS have multiple interfaces and participate as gateways during connecting to Internet. Due to this problem, there is a need to revaluate the existing routing protocols for ad hoc networks and propose right routing protocol for wireless mesh environment. While choosing suitable routing protocol for mesh network, it is needed to consider the issue of scalability. Jiwei Chen et al., [14] developed and analyzed the extension of OLSR routing protocol , called Optimized Fisheye Link State Routing (OFLSR) to reduce routing overhead, then compare OFLSR with AODV in terms of packet delivery ratio, throughput, routing overhead and packet end-to-end delay.

The architecture of multi-channel wireless mesh net work which provides every mesh network node with number of 802.11net work inter face cards is presented in Raniwala et al [16].Such kind of architecture is known as Hyacinth. In [15], it is also presented that intelligent assignment of channel is very critical to the performance of such multichannel wireless mesh net work architecture. The authors also compared the performance of such distributive algorithm with centralized algorithm that does similar task in their simulation part of study.

The project for autonomic computing model presented in [17], clearly explains how in heterogeneous environment, the applications of autonomic computing are carried out in open system architecture and required initiatives for industry standards. Such model also shows that in an evolutionary manner how self managing autonomic abilities are achievable. Vandenberghe et al [18] has presented an architecture for a system where he has explained how the system is capable of dealing with the restricted and contradictory requirements in building the wireless automation. Mobi Mesh is another architecture for wireless mesh network and is given [19] and this architecture has been implemented in a real life test bed and this architecture supports great mobility and offers integration abilities. Set of procedure that constitutes an intermediate layer between second and third layers support mobility. The performances and test results are highlighted and future works are described.

III. SELF-CONFIGURING MODEL FOR SCALABLE HYBRID MESH PROTOCOL

The scalable capabilities include: Self Configuration, Self Optimization and Self Healing [23][25][24] which is appear along with the sub layers of HWMP protocol. The scalable capabilities are not entirely independent and have strong correlation. In this model, we have utilized the control loop as the main mechanism responsible for analyzing events and making important decisions according to protocols used. The figure 1 shows the scalable approach in a WMN scenario in which mesh routers and gateways can be connected to a wired network in order to provide access to the Internet gateways. The communication between the mesh clients and mesh routers are done through 802.11s standard. The application layer agents: Populating-Agent (PA) and Observing-Agent (OA) are involved in self configuration and self optimization tasks. The transport layer agent: Healing-Agent (HA) is involved in self healing of the network. The mesh client nodes are all connected to a specific mesh routers depending upon on the visibility and coverage of the respective mesh router.

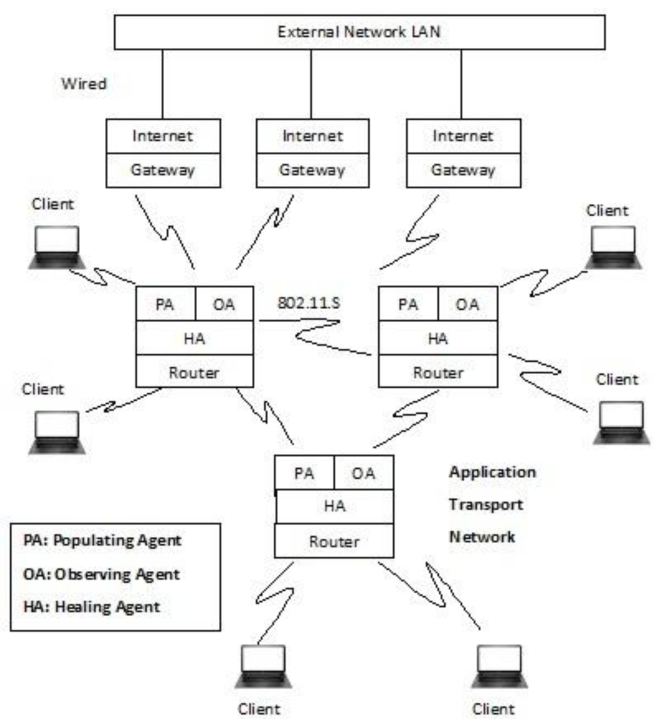

Fig. 1 Proposed overview model of scalable capabilities incorporated in Wireless Mesh Networks

The agents in the application layers have got clear responsibility in self organization and self optimization.

PA-Agents: These mobile agents are placed in the mesh router and also in each association of the client node of the mesh router. These agents have got specific functions in identifying the population or density of the network. The density of the network may vary between the small scale, medium scale and large scale. The group of PA-Agents forms the base of self configuration capability of HWMP.

OA-Agents: These mobile agents are placed in the mesh router and also in each association of the client node of the mesh router. These agents are responsible for observing the network behavior such as drop packets rate, signal strength and range, throughput, delay, active and passive nodes, as well as information about the link state. They are fixed agents in the mesh routers and allow self optimization capability of HWMP.

The agent in the transport layer has got clear responsibility in self healing process during network formation.

HA-Agents: These mobile agents are placed in the mesh router and also in each association of the client node of the mesh router. These agents have got specific functions in healing the mesh router when the population or density of the network increases suddenly. The density of the network may vary between the small scale, medium scale and large scale. The group of HA-Agents forms the base of self healing of HWMP.

(i) SELF-CONFIGURATION PROCEDURE

This module is responsible for configuring parameter values in the SHWMP and HWMP protocols depending on the network density. The performance of the SHWMP and HWMP protocols is sensitive to the select values of some parameters that can be adjusted during increasing in the network size. The self-configuration process self-adapts the values conform to changes in the network density, thus not avoiding the default values for these parameters in the networks.

IV. SIMULATION ENVIRONMENT

The simulation experiments are conducted using QualNet Simulator [25]. The standard IEEE 802.11s radio is adopted with the channel rate as 2 Mbps. The scenario with mesh of wireless routers for the backbone client nodes (fixed and mobile) connected to the each mesh routers. The transmission range is 250m and the carrier sensing range is around 600 m. The simulation area of 2000 x 2000 m^2 is deployed over a square geographical area. The client nodes have different mobility. These settings are maintained with real time wireless networks, in which the transmission range of a node is typically smaller than its interference range. The Random Waypoint model [27] is adopted for driving mobile hosts. In this model, each host starts its movement from a random location to a random destination with a randomly chosen speed uniformly distributed between 0 and a maximum speed. Once after reaching the destination, node will choose targeted another destination is selected. The simulation parameters are listed in the Table I.

Table I. Simulation Parameters

Mesh Client: Varying mobility (5 – 20 m/s)	Antenna: Omni
Mesh Router: Most of them are static	Transport: TCP and UDP
Radio: Two Ray Ground	Queue Type and Size: FIFO and 50
Layer PHY: 802.11s	Simulation time: 800s

V. RESULTS AND DISCUSSIONS

The performance of Self configuring HWMP protocol is evaluated with HWMP with varying traffic loads and number of nodes. Simulations are carried out using qualitative metrics and improvements are seen through the promising results.

A. Throughput and Delay against Traffic Loads

In this scenario, the number of nodes is fixed to 200 and traffic load is varied from 20 packets/s to 200 packets/s. The nodes are placed randomly within 2000 m x 2000 m area. The performance of the four routing protocols in terms average throughput with various number of traffic loads are depicted in the figure 2. The average throughputs of HWMP routing protocols are decreasing as the number of traffic loads increased.

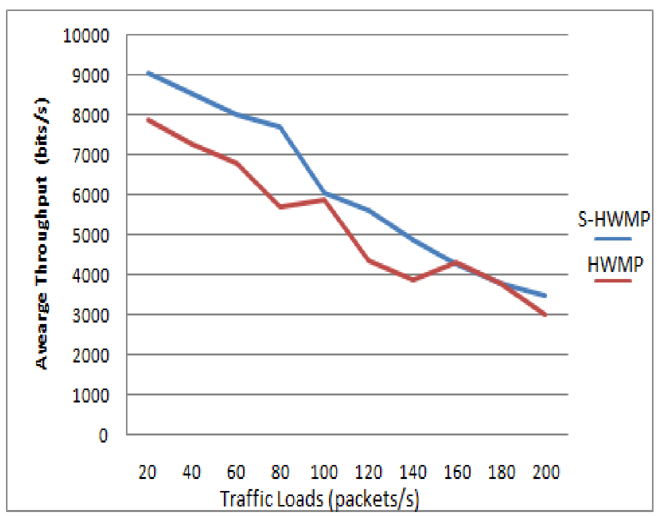

Fig. 2. Average Throughput versus Traffic Loads

Among the Self Configuring HWMP (SHWMP) and HWMP routing protocols, SHWMP attained highest throughput as the number of traffic loads increased. This is due to the SHWMP protocol sends more data packets and drops fewer packets. The nodes in the mesh networks simultaneously send less maintenance messages periodically and have got sustainability in the network. It can be observed that SHWMP has got clear throughput higher than HWMP. This is because of the self-configuring capability of HWMP over varying traffic loads.

In fig. 3 the average end to end delay is added in the network. Here it can be seen that the SHWMP has lowest average end to end delay throughout simulation as compared to HWMP routing protocols. It can seen clearly that, the average end to end delay for SHWMP is nearly130 milliseconds and found to be consistent throughout the simulation as the traffic load is increased. HWMP recorded up to 280 milliseconds. This is very high delay due to the required overhead to broadcast control signal throughout the mesh networks. The adjustment parameter of time interval makes SHWMP more reliable.

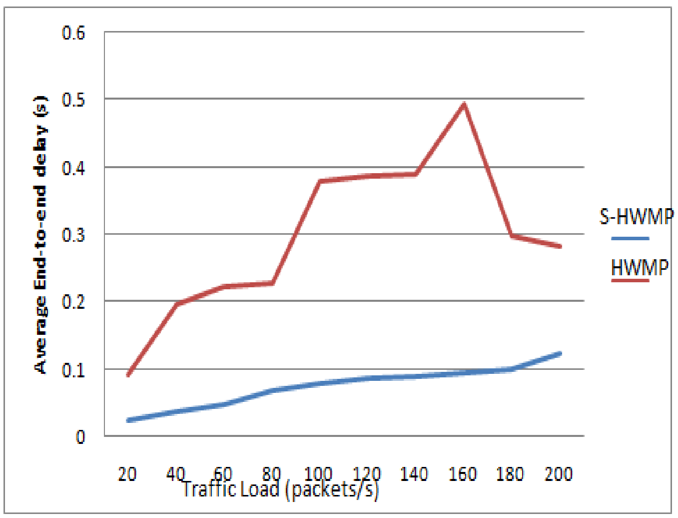

Fig. 3. Average end to end delay versus Traffic Loads

B. Throughput and Delay against Network Size

The change in number nodes from 20 to 200 nodes keeping 15 sources of CBR traffic transmitting at the rate of 100 packets per seconds are placed randomly over a simulation area of 2000 m x 2000 m area. Initially both SHWMP and HWMP protocols demonstrate the more or less same value as shown in the figure 4. But when the number of nodes increases, the throughput of HWMP protocol is degraded drastically.

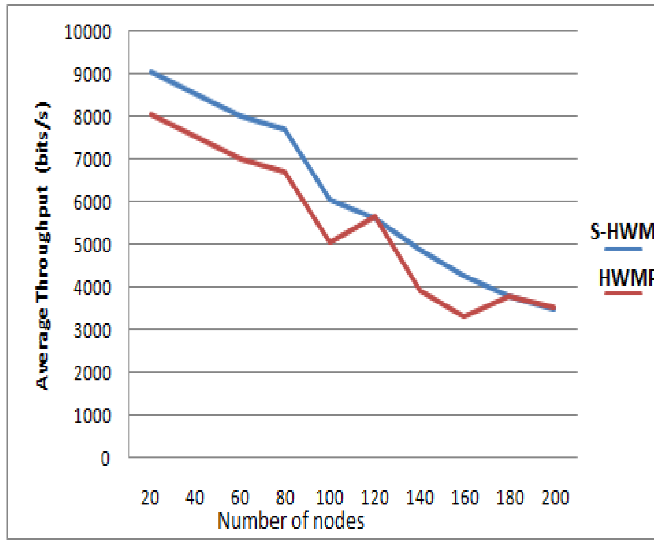

Fig. 4. Average Throughput vs Number of Nodes

This performance degradation is mainly due to increasing number nodes leads to increase in packet drops within the mesh networks. SHWMP gives consistent throughput the simulations compared to HWMP. SHWMP is a clear winner of HWMP. The main reason for degradation of HWMP protocol is due to high over loaded due to change messages in the network due to increase in number of nodes. The average end to end delay is measured from source to destination over a varying number of nodes as shown in figure 5. The increase in number of nodes will have direct effect on average end to end delay. This results in increase of end to end delay when network size grows as shown in figure 6.

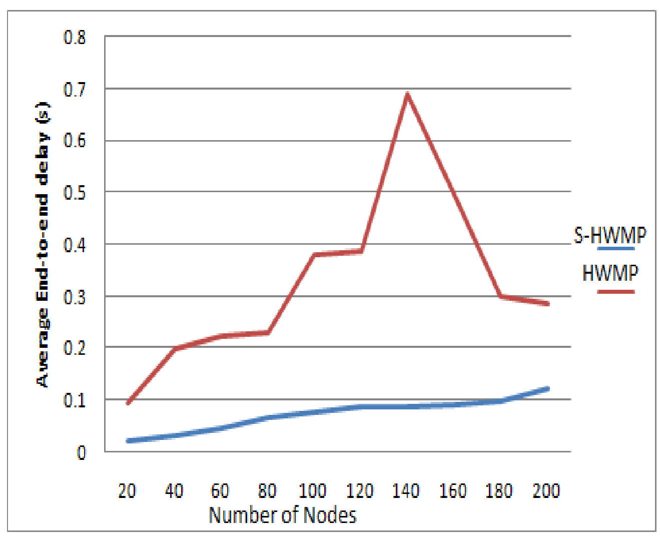

Fig. 5. Average Throughput versus Number of nodes

Both SHWMP and HWMP incur nearly 50 to 200 milliseconds of average end to end delay throughout this simulation. Due to large network size HWMP fail to carry out the load efficiently. SHWMP shows a consistent lowest average end to end delay which indicates that protocol can be used for large scalable mesh networks.

VI. CONCLUSION

In this paper, a self configuring hybrid mesh protocol (SHWMP) is proposed for wireless mesh networks based on the self-configuring mechanism. The basic idea is to adapt the self organization capabilities in to HWMP protocol which in turn improves the scalability of the network and increases the routing performance. To study the behavior with hybrid protocols SHWMP and HWMP which shows clear impact on performance when there is a change in network density, number of sources and different traffic loads. The self configuration module is implemented and evaluated under different network scenarios and traffic conditions. Through the self configuring process, dynamically certain parameters are tuned to the time intervals of HELLO message broadcasts depending on the density of the network. It was clearly observed through our simulations that SHWMP has clear advantage over HWMP. The overall average throughput and lowest end to end delay recorded in SHWMP makes clear winner amongst other routing protocol used in this simulation.

REFERENCES

[1] K. Kowalik and M. Davis, "Why Are There So Many Routing Protocols for Wireless Mesh Networks?," Irish Signal and Systems Conference, Dublin, 2006.

[2] J.H. Li, W. Peng, R. Levy, A. Staikos, M. Chiang, "On systemic cross-layer design for ad-hoc networks," Military Communications Conference, 2008. pp. 1-7, November 2008.

[3] V. Kawadia, P.R. Kumar, "A cautionary perspective on cross-layer design," IEEE Wireless Communications 12(1), pp.3-11. February 2005.

[4] X. Lin, N.B. Shroff, R. Shrikant, "A tutorial on cross-layer design," IEEE Journal on Selected Areas in Communications, 24(8), pp. 1452-1463. August 2006.

[5] G. Thamilarasu, R. Sridhar, "Exploring cross-layer techniques for security: challenges and opportunities in wireless networks," IEEE Military Communications Conference, MILCOM'07, pp. 1-6, October 2007.

[6] S.M.S. Bari, F. Anwar, M.H. Masud, "Performance Study of Hybrid Wireless Mesh Protocol (HWMP) for IEEE 802.11s WLAN Mesh Networks., International Conference on Computer and Communication Engineering (ICCCE-2012),3-5 July 2012, Kuala Lumpur, Malaysia, pp712-716, 2012.

[7] M. Bahr, "Proposed Routing for IEEE 802.11s WLAN Mesh Networks", The 2nd Annual International Wireless Internet Conference, Boston, pp 6-13, 2006.

[8] Charles E. Perkins, Elizabeth M. Royer, *Ad hoc On-Demand Distance Vector Routing.*, Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, February 1999, pp. 90-100.

[9] T. Clausen, P. Jacquet, *Optimized Link State Routing Protocol (OLSR)*, RFC3626, 2003.

[10] C. Ying, Q. Lv, Y. Liu, M. Shi, *Routing protocols overview and design issues for self-organized network,* In Proc. of InternationalConference on Communication Technology (WCC-ICCT 2000), Vol. 2, 2000.

[11] E.M. Royer, C.K. Toh, *A review of current routing protocolsfor ad hoc mobile wireless networks,* IEEE Personal Communications, vol. 6, no. 2, Apr. 1999.

[12] S.R. Das, C.E. Perkins, E.M. Royer, *Performance comparison of two on-demand routing protocols for ad hoc networks*, In Proc. 19th INFOCOM, vol. 1, 2000.

[13] C.E. Perkins, E.M. Royer, S.R. Das, M.K. Marina, *Performance comparison of two on-demand routing protocols for ad hoc networks,* IEEE Personal Communications, vol. 8, no. 1, Feb.2001.

[14] C. Adjih, E. Baccelli, T.Clausen, P. Jacquet, R. Rodolakis, *Fish Eye OLSR Scaling Properties,* IEEE Journal of Communication and Networks (JCN), Special Issue on Mobile Ad Hoc Wireless Networks, Dec. 2004.

[15] Microsoft, "Self-Organizing Wireless Mesh Networks ," http://research.microsoft.com/mesh/ 2005.

[16] A. Raniwala and T. Chiueh, "Architecture and Algorithms for an IEEE 802.11-Based Multi-Channel Wireless Mesh Network," 24th Annual Joint Conference of the IEEE Computer and Communications Societies(Infocom). Proceedings IEEE, vol. 3, pp. 2223–2234, March 2005.

[17] J. O. Kephart and D. M. Chess, "The Vision of Autonomic Computing," in IEEE Computer Networks 36, vol. 1, 2003, pp. 41–50.

[18] W. Vandenberghe, B. Latre, F. D. Greve, P. D. Mil, S. V. den Berghe, K. Lamont, I. Moerman, M. Mertens, J. Avonts, C. Blondia, and G. Impens, "A System Architecture for Wireless Building Automation,"Mobile and Wireless Communication Summit, Myconos, Greece, 2006.

[19] A. Capone, S. Napoli, and A. Pollastro, "MobiMESH: An Experimental Platform for Wireless MESH Networks with Mobility Support," First International Workshop on Wireless mesh: moving towards applications - WiMeshNets, 2006.

[20] N. Malheiros and E. Madeira, "Autonomic wireless mesh networks: An architecture to wireless mesh networks selfmanaged," Workshop of thesis and dissertations: institute of

Computer science, State University of Campinas, December 2006, access in 12 of march the 2007. [Online]. Available:http://solimoes
.ic.unicamp.br:8080/wtd/apresentacoes/malheiros

[21] A. Malatras, G. Pavlou, S. Gouveris, and S. Sivavakeesar, “Selfconfiguring and optimizing mobile ad hoc networks,” Proceedings of the Second International Conference on Autonomic Computing (ICAC05), 2005.

[22] 802.11 Working Group of the IEEE 802 Committee IEEE P802.l1s/D4.01 Draft Standard. IEEE; Washington, DC, USA: 2010.

[23] O. Babaoglu, M. Jelasity, A. Montresor, C. Fetzer, S. Leonardi, A. van Moorsel, and M. van Steen, SelfStar Properties in Complex Information Systems. Springer, 2005.

[24] J. O. Kephart and D. M. Chess, “The Vision of Autonomic Computing,” in IEEE Computer Networks 36, vol. 1, 2003, pp. 41–50.

[25] A Boukerche, L Guardalben, J B M Sobral and M S M A Notare, “A performance Evaluation of OLSR and AODV Routing Protocols Using a Self Configuation Mechanism for Heterogeneous Wireless Mesh Networks”, 33rd International Conference on Local Area Netowrks, 2008, pp. 697-704.

[26] QualNet Network Simulator. http://www.scalable – networks.com

[27] T. Henderson,boeing, S. Floyd et.al., "The NewReno Modification to TCP's Fast Recovery Algorithm", University of Oulu, WIDE Project, April 2012, ISSN: 2070-1721

[28] Esa Hyytiä and Jorma Virtamo. Random waypoint model in cellular networks. Wireless Networks, Online First, 2006

[29] T.Claausen and P.Jacquet, “Request for comments:3626”, Project Hipercom INRIA, Tech. Rep., October 2003

[30] C. Perkins, E. Belding –Royer, and S. Das, “Request for comments: 3561”, Tech Rep. 2005.