PERFORMANCE COMPARISON OF MESH ROUTING PROTOCOLS IN AN EXPERIMENTAL NETWORK WITH BANDWIDTH RESTRICTIONS IN THE BORDER ROUTER

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ABSTRACT

In recent years, a new technology known as wireless mesh networks (WMNs) has emerged as an adaptable and economical extension of wired networks, which, in some scenarios and applications, may provide a more affordable and versatile solution than other wired or wireless technologies. In this paper, we propose to use WMNs to provide Internet access to low-income people living in Caracas city. Caracas has a geographical distribution such that almost every middle-class and wealthy neighborhood is located next to at least one poor neighborhood, so poor families may access the Internet via one or more Internet Service Providers contracted by a neighbor living in a surrounding middle-class or wealthy neighborhood. Computers in poor neighborhoods can connect to the mesh networks via wireless adaptors. As a first step, we investigate the performance of the mesh network for Babel, B.A.T.M.A.N., and OLSR routing protocols as a function of the throughput and packet loss rate for different test scenarios defined according to the number of mesh nodes and the bandwidth constraints applied by the border router. The results show that when the bandwidth is more limited, all the routing protocols provide similar values of throughput; as the bandwidth restrictions are relaxed, Babel and B.A.T.M.A.N., perform better than OLSR for large number of users. For small network sizes, the routing protocols behave similarly.

Keywords: Wireless mesh networks, Proactive routing protocols, OLSR, B.A.T.M.A.N., Babel.

COMPARACION DEL RENDIMIENTO DE LOS PROTOCOLOS DE ENRUTAMIENTO PARA REDES MALLADAS EN UNA RED EXPERIMENTAL CON RESTRICCIONES DE ANCHO DE BANDA EN EL ENRUTADOR DEL BORDE

RESUMEN

En los últimos años, una nueva tecnología conocida como Redes Inalámbricas Malladas (WMNs – Wireless Mesh Networks) ha emergido como una extensión adaptable y económica de las redes cableadas que, en algunos escenarios y aplicaciones, pueden ofrecer soluciones más versátiles y costeables que otras tecnologías de redes cableadas o inalámbricas. En este artículo, se propone usar las WMNs para proveer acceso a Internet a personas de bajos ingresos que viven en la ciudad de Caracas. Caracas tiene una distribución geográfica en la cual la mayoría de las urbanizaciones pudientes y de clase media se encuentran adyacentes a un vecindario de bajos recursos, en donde sus habitantes podrían acceder a Internet vía uno o más proveedores de servicios contratados por un vecino ubicado en una urbanización con mayores recursos. Los computadores en los vecindarios de bajos recursos se pueden conectar a la red mallada a través de adaptadores inalámbricos. Como primer paso, se investigó acerca del desempeño de las redes malladas para los protocolos de enrutamiento Babel, B.A.T.M.A.N., y OLSR en función del throughput y la tasa de pérdida para diferentes escenarios definidos de acuerdo al número de nodos mallados, y a las restricciones del ancho de banda aplicadas por el enrutador de borde. Los resultados muestran que cuando al ancho de banda es más limitado, todos los protocolos de enrutamiento proveen valores similares de throughput; a medida que las restricciones de ancho de banda se relajan, Babel y B.A.T.M.A.N. tienen mejor desempeño que OLSR para un elevado número de usuarios. Para redes pequeñas, todos los protocolos poseen conductas similares.

Palabras Clave: Redes Malladas, Protocolos de enrutamiento proactivos, OLSR, B.A.T.M.A.N., Babel.

INTRODUCTION

In recent years, a new technology known as wireless mesh networks (WMNs) has emerged as an adaptable and economical extension of wired networks, which, in some scenarios and applications, may provide a more affordable and versatile solution than other wired or wireless technologies; the applications of the WMNs include to extend the coverage areas such as buildings, campuses; to provide network connection to areas that are difficult to wire, such as a golf course or a highway; and to provide a communication solution in difficult environments such as battlefield and disaster recovery. Mesh networks combine fixed and mobile nodes interconnected via wireless links to create a mobile ad hoc network (MANET), which may be defined as a collection of self-configured and self-organized mobile nodes connected into a temporary and arbitrary topology without a preexisting infrastructure.

Moreover, today, Internet access for various purposes, such as searching for information and to access services (e.g. email, banks), is a necessity. Such access is provided by the Internet Service Providers (ISPs) who usually charge for this service, thus being not accessible to people who have low incomes, especially those living in poorest areas of cities. The city of Caracas has a geographical distribution such that almost every middle-class and wealthy neighborhood is located next to at least one poor neighborhood. For example, in Figure 1, we can see that the poor area of Los Manolos is surrounded by the middle-class neighborhood of Las Palmas. People living in middle-class and wealthy neighborhoods often pay for Internet access service, which is usually provided 24 hours a day, 365 days a year. However, this service is underutilized during the hours when users are away from home (working or studying). Most people who live in poor neighborhoods can´t afford this service because of their low annual income.

Figure 1. *Photo shows the poor neighborhood of Los Manolos (circled) surrounding by Las Palmas in Caracas city*

This paper proposes a way to alleviate this problem through the use of mesh networks. The idea is that poor families access the Internet via one or more ISPs contracted by a neighbor living in a surrounding middle-class or wealthy neighborhood. This could be achieved through the use of wireless routers (Internet ingress/egress points) located close to the borders between both neighborhoods and whose scope extends to one or more poor housings. Computers located in the houses in the poor neighborhood and the egress points will be connected to the mesh network using Wi-Fi or other data link layer technology. Thus, user information data will travel from the mesh network to the Internet and from the Internet to the mesh network via the ingress/egress point.

In order to not devalue the performance of the shared Internet connection, a limit on the use of the network resources must be established. For example, the user who pays for the Internet access service may want to share only 50% of the total bandwidth. Today, several low cost wireless routers may be configured to do that. More complex sharing restriction requirements may involve using a more sophisticated device located between the ingress/egress point and the mesh clients.

Many key challenges issues of the WMNs have been discussed widely (Akyildiz & Wang, 2005; Waharte *et al.* 2010). Routing protocols are one of these issues. Despite the existence of several routing protocols for adhoc networks, the design of routing protocols for WMNs is still an open research area. Questions, such as scalability, better performance metrics, MAC-layer interaction, and efficiency still remain unresolved. Thus, we initially want to evaluate some routing protocols for the proposed solution in terms of throughput, and packet loss as a function of the available Internet access connection bandwidth. We study three traditional MANET-like routing protocols that have been already used in WMNs; they are Optimized Link State Routing (OLSR) (Clausen &Jacques, 2003), Babel (Chroboczek, 2010) and Better Approach To Mobile Ad hoc Networking (B.A.T.M.A.N.) (Johnson *et al.* 2008).

The performance of the three routing protocols (OLSR, Babel and B.A.T.M.A.N.) has been compared in several papers. For example, Murray *et al.* (Murray, Dixon, Koziniec, 2010) evaluate experimentally the three protocols in terms of packet delivery ratios, bandwidth and routing protocol overheads. Abolhasan *et al.* (Abolhasan, Hagelstein, 2009) also investigate the performance of those routing protocol in a real-world testbed. The performance metrics used are the optimal bandwidth, packet delivery ratio, round trip delay and route converge latency. However, none of these considers bandwidth restrictions on the Internet border router in the experimental scenarios.

The rest of the paper has been organized as follows. Section 2 describes the routing protocols used in our study. In section 3, we explain the experimental testbed, the performance metrics, and the tools used in the research. In section 4, we present and discuss the results. Finally, section 5 concludes the paper and presents future works.

ROUTING PROTOCOLS

Routing protocols for WMNs have similar properties as the protocols for MANETs; however WMN routing protocols also need to capture other features, such as lower mobility of the nodes and not on power consumption constrain. So, currently, the development of protocols that work optimally in this type of network is an open research area. Thus, in this paper, we utilized three protocols used in MANET that have been widely adopted in the mesh networks: OLSR, Babel and B.A.T.M.A.N. They are categorized as proactive protocols, which establish and maintain data paths to destinations by periodically distributing routing tables throughout the network, so paths for nodes are usually available whether there is data to be transmitted or not. Conversely, in the reactive protocols, a route discovery is initiated only on demand from any source node. A detailed study of wireless mesh networks is out of the scope of this paper; however some description can be found in (Abolhasan *et al.* 2009). In this section, we describe the three protocols used in our research.

B.A.T.M.A.N.

B.A.T.M.A.N. algorithm focuses exclusively on learning about the best next hop for each destination (Murray *et al.* 2010). It does not try to discover or calculate entire routing paths. In B.A.T.M.A.N. all nodes periodically broadcasts originator messages (OGMs) to their neighbors, which in turn re-broadcast these messages. Route selection for destinations is based on the number of OGMs received from a node for that destination. The OGMs are small and include the address of the source node, the address of the node which re-broadcast the message, a time to live, and a sequence number. They are encapsulated in UDP packets.

OLSR

OLSR (Clausen & Jacques, 2003) uses the classic link state algorithm improved to work more efficiently on wireless networks. It introduces the use of multipoint relays (MPR) that are selected nodes which forward packets on the network (see Figure 2). This substantially reduces the number of required transmissions and hence the traffic compared to other mechanisms where all nodes forward packets which have been received for the first time. Each node selects a set of its neighbor nodes as MPRs, and each node knows the set of neighbors for which it is a MPR. Information about the topology of the network is shared between MPRs to build and maintain their routing tables.

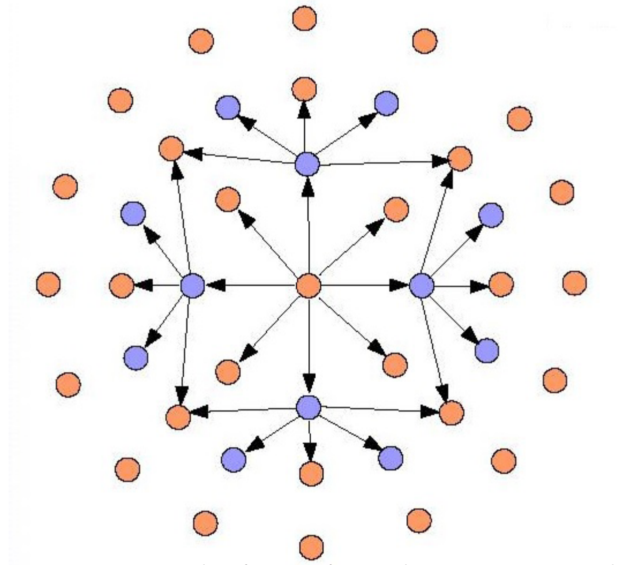

Figure 2. *Example of OLSR forwarding using MPR nodes*

BABEL

Babel is based on distance-vector algorithm (Abolhasan *et al.* 2009). It senses link quality for computing route metrics using a variant of the Expected Transmission Count (ETX) algorithm (Murray *et al.* 2010). The route selection is based on historical information about the link quality avoiding situations where a node frequently changes its favorite route to a destination, which may lead to route instability. Also, the protocol reactively sends a route information request when it detects a link failure, so given that the route metrics where calculated at the initialization stage, Babel speeds up convergence. Each node periodically sends hello messages on each of its interfaces, each messages is identified by a sequence number. Also, each node periodically sends IHU (I Heard You messages) to each of its neighbors, from which it has received a hello message recently. Then, the node can calculate the cost of the link to each neighbor from which it has received routing information (carried in both hello and IHU messages).

Each node sends route update packets on all its interfaces. A node can also send a route request packet, which is associated with the prefix of the selected route. The node that receives this route request checks its routing table and looks for an entry with the prefix, and if the route exists it sends a route update package.

EXPERIMENTAL TESTBED

The evaluation of the routing protocols is conducted in an indoor multi-hop mesh network testbed using HP Workstations xw4600 with CPU Intel Core 2 Duo 2.66 GHz, 2 GB RAM and IEEE 802.11g wireless NIC (Figure 3). The multi-hop network is connected to the network Lab via a gateway and a wireless router Linksys WRT54GL. The gateway has the same features as the mesh nodes and is running the wondershaper tool to apply bandwidth restriction in the ingress/egress router. We also install a server in the wired Lab network to carry the experimental tests (Figure 3). The mesh nodes and gateway are running Linux Ubuntu version 10.04 and the following routing protocol distributions: Babel version 1.0.1, B.A.T.M.A.N. version 0.3.2, and OLSR version 0.5.6-r7.

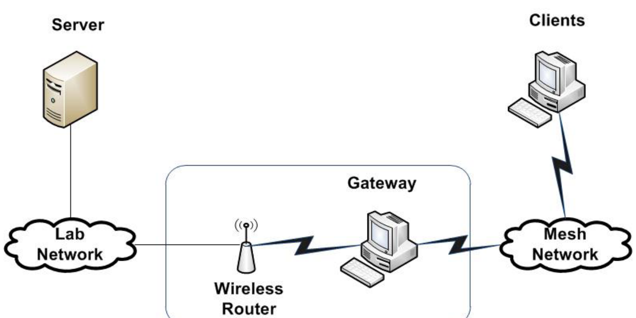

Figure 3. *General configuration of the testbed network*

In Figure 3, the clients represent the wireless devices (e.g. laptops) located in some houses or buildings in the poor neighborhood (e.g. in Los Manolos) and are connected to the mesh network. The gateway represents a mesh device located in a place (e.g. a house or a building) close to the border between the poor neighborhood and the wealthy neighborhood. The wireless router represents the access point placed in the wealthy neighborhood. Finally the Lab network and server represent the Internet access network and an Internet server which may be situated in any place around the world, respectively.

The mesh network topology is chosen so the nodes are distributed arbitrary, and the nodes are one or two hops apart from the gateway. Also, in this study, we measure the throughput and packet loss rate over several scenarios. Thirty-six testdbed scenarios are defined based on three parameters: bandwidth restriction on the ingress/egress router, number of mesh nodes, and packet size. The following restrictions over the total available bandwidth of 1024 Kbps for each downstream and upstream link are applied for the mesh network: 25%, 50%, and 100% (the latest means no restriction). The comparative tests are performed for the following number of mesh nodes: 5, 15, and 25, and for the following packet sizes: 64, 256, 1024, and 1518 bytes according to the recommendation given in (Bradner, 1991). The only type of network traffic produced is HTTP.

We use DITG (Dainotti *et al.* 2012) to produce traffic and to measure the throughput. The tests are repeated 10 times for each scenario. To measure pack loss rate we use the ping tool. Five hundred (500) ping requests are sent for each network size (e.g. 5, 15, or 25 nodes for network).

RESULTS AND DISCUSSION

In this section, we only show the results for the packet size of 1518 bytes, which is representative of our study; other results can be found in (Balderrama & Colombo, 2010). Figure 4, presents the network throughput defined as the average rate of data delivery over the network measured in data packets per second as a function of the percentage of ingress/egress bandwidth available for the mesh nodes. The results show that with a restriction of 25% of the total available bandwidth, the three routing protocols behave similarly, while when these restrictions are relieved, B.A.T.M.A.N. and BABEL protocols outperformed OLSR. Moreover, when the bandwidth is not restricted, Babel provides higher throughput. Two similar comparative studies (Abolhasan *et al.* 2009; Murray *et al.* 2010) agree that Babel offers greater throughput than both B.A.T.M.A.N. and OLSR. Also, these studies (Johnson *et al.* 2008; (Murray *et al.* 2010) concurs that B.A.T.M.A.N. behaves better than OLSR in similar testbed scenarios of ours. However, in (Abolhasan *et al.* 2009), OLSR produces a higher throughput than B.A.T.M.A.N. We think that the differences in the results are related to the different aspects taken into account in each experimental testbed, such as configuration of the protocol, network variables and network topologies used.

In Figure 5 to Figure 7, we compare the throughput as a function of the number of mesh nodes. It is seen that, when the available bandwidth is 25% of the total (Figure 5), all the routing protocols behave similarly regardless of the number of nodes. Otherwise, when the bandwidth restrictions are relaxed (Figure 6 and Figure 7), BABEL and B.A.T.M.A.N. provide better throughput than OLSR for network sizes of 15 and 25 mesh nodes. For a small network of 5 mesh nodes, the three protocols perform similarly.

Figure 8 shows the average of packet loss rate for the three protocols. Babel offers a lower rate of lost packets than B.A.T.M.A.N. and OLSR. This is because Babel takes into account the link quality using a variant of ETX algorithm in the route selection. In the scenarios with no bandwidth restrictions, OLSR offers a lower rate of lost packets that B.A.T.M.A.N., while in the other scenarios, three protocols perform similarly.

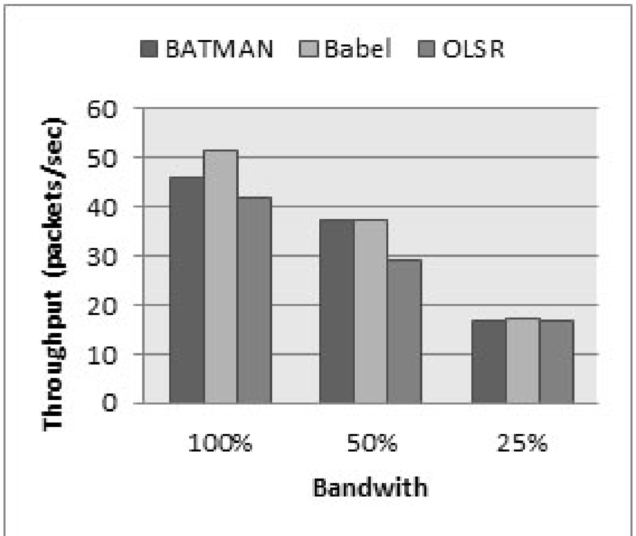

Figure 4. *Throughput per routing protocol versus percentage of bandwidth available for the mesh network on the border router for a mesh network of 15 nodes*

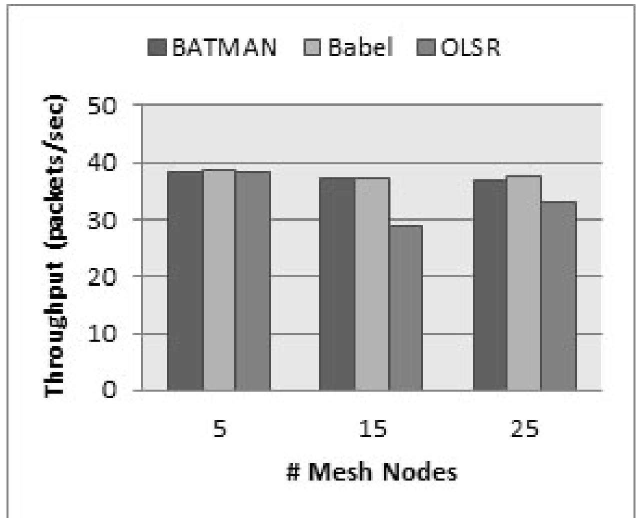

Figure 6. *Throughput per routing protocol versus increasing number of mesh nodes when the ingress/egress bandwidth is limited to 50% of the total available bandwidth*

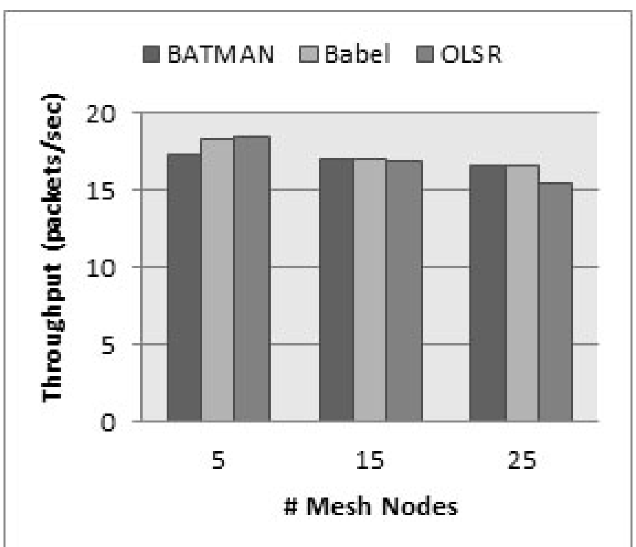

Figure 5. *Throughput per routing protocol versus increasing number of mesh nodes when the ingress/egress bandwidth is limited to 25% of the total available bandwidth*

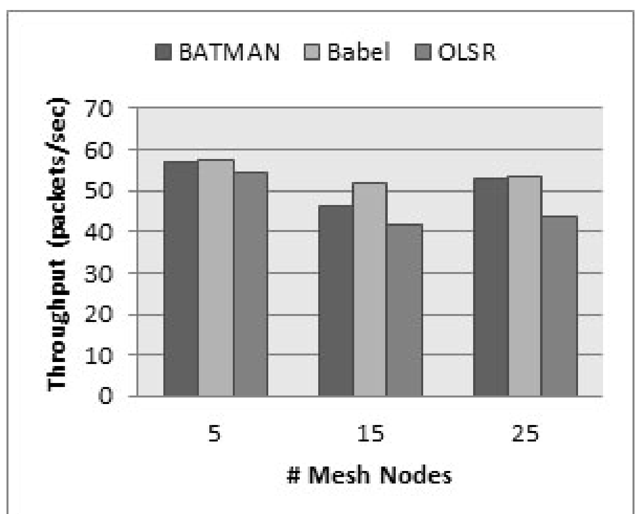

Figure 7. *Throughput per routing protocol versus increasing number of mesh nodes when the ingress/egress bandwidth is limited to 100% of the total available bandwidth*

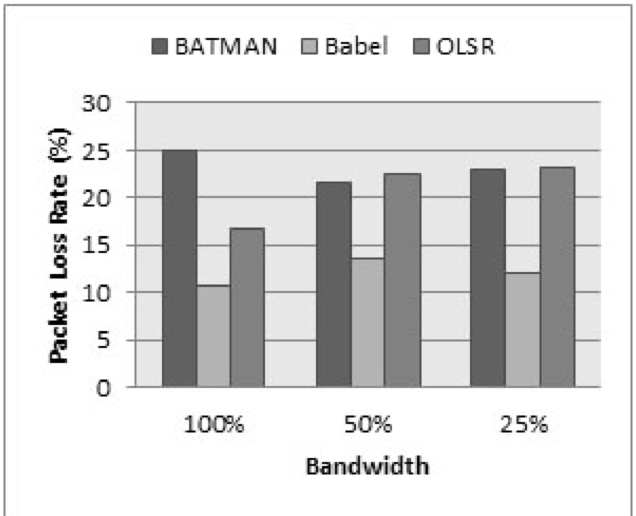

Figure 8. *Percentage of packet loss per routing protocol versus percentage of bandwidth available for the mesh network on the border router for a mesh network of 15 nodes*

CONCLUSIONS

In this work, we present a proposal to provide free Internet access to users who live in poor neighborhoods of Caracas city. The solution exploits the geographical distribution of poor and wealthy or middle-class neighborhoods in the city and uses the emerging Wireless Mesh Network technology. This proposal provides an alternative to access networks such as fiber optic links and digital subscriber lines (DSLs). Compared to its competitor technologies, our proposal is easier and economical to deploy.

As a first step, we evaluate three traditional MANET-like routing protocols: B.A.T.M.A.N., Babel, and OLSR, which have been already used in WMNs. The routing protocols are compared in an experimental testbed when some ingress/egress bandwidth restrictions on the total available bandwidth are applied. The protocols are compared in terms of two performance measurement: throughput and packet loss rate.

The results show that when the bandwidth is more limited, all the routing protocols provides similar values of throughput; as the bandwidth restrictions are relaxed, Babel and B.A.T.M.A.N. perform better than OLSR for large number of users (15 or more). For small network sizes (5 mesh nodes), the three routing protocols behaves similarly. On the other hand, the packet loss rate is reduced considerably when Babel is used. Thus, being able to perform same or better than the other protocols, Babel seems to be a good choice to be used in the WMN proposed in our study.

This work has focused on the study of some routing protocols for a particular mesh network application (i.e. Internet access). However, there are other aspects which may affect the design of a mesh network (Akyildiz, Wang, 2005), so future works may include studying how some factors, such as radio and MAC layer techniques, influence the performance of the proposed network. In addition, other future works include examining reactive protocols for our study case and comparing the results with the ones obtained so far. We would also like to evaluate the network when other type of traffic is generated such as video and audio. Furthermore, we expect to compare the performance of the network when the bandwidth is adaptively changed according to some parameters such as time of the day.

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