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Overhead impact on ad hoc mobile networks

(Impacto de la sobrecarga en redes móviles ad hoc)

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Abstract:
Overhead quantifies how much routing and control information is necessary for the application data to reach the destination node. This is very important in Ad Hoc networks because the mobility of nodes makes routing paths change constantly, therefore, the exchange of control and routing information increases. In this work the overhead for AODV, BCHP and DSVD mobile routing protocols is analyzed. Protocol reliability is used like a metric based on overhead behavior. The results show that the overhead can be between 30% to 60% with respect to the total throughput. BCHP is the most effective protocol because with similar expected overhead it has a better level of application information delivered.

Keywords: mobile ad hoc network overhead; mobile routing protocols; ad hoc network reliability; AODV; overhead impact.

Resumen:
La sobrecarga es la medida de la cantidad de información de control y de enrutamiento necesaria para la entrega efectiva de la información de aplicación. Es muy importante en redes móviles Ad Hoc debido a que la movilidad de sus nodos hace que los caminos de enrutamiento cambien constantemente, por lo tanto, es más frecuente el intercambio de información de control y de enrutamiento con el objetivo de mantener los servicios de red disponibles. Este artículo mide la sobrecarga para los protocolos de enrutamiento AODV, BCHP y DSDV en redes móviles. De la misma manera, se relaciona la sobrecarga con la confiabilidad del protocolo. Los resultados muestran que la sobrecarga va desde el 30% a 60% respecto al total del caudal de la red. BCHP es el protocolo con un nivel de sobrecarga similar al resto de protocolos pero con mejor nivel de entrega efectiva de información.

Palabras clave: sobrecarga en redes móviles ad hoc; protocolos de enrutamiento; impacto de sobrecarga.

1. Introduction

Mobile Ad hoc NETworks (MANET) are auto-configurable networks, their nodes can act as source and destination simultaneously. Mobile nodes have limited resources, for instance, memory, energy and network buffers. Moreover, these resources are consumed in processes like information exchange, path selection and routing tasks. When the nodes act as routers, they must exchange information with the aim of share and update their routing data.

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Control data allows the network to maintain adequate levels of performance, reliability, and convergence. Control data mainly is used by the nodes to keep the routing table updated. The control data exchanges information depending on the type of routing protocol used, by example a routing protocol could use several small packets to determine the availability of its neighboring nodes.

The routing and control data transmitted (Tran et al., 2015) into the network is called control routing, which is necessary for the network reliability. As an example, if the network path is modified by link failure or if the nodes are busy, these new issues should be immediately notified to all the nodes in the network in order to achieve a fast convergence.

The ratio between control routing and data transmitted is named overhead. A special network goal is to keep a trade-off between the throughput and the network reliability, with an acceptable level of overhead. For instance, a low level of overhead causes that the network uses the maximum effective throughput possible with the lowest reliability. On the other hand, a high level of overhead increases the reliability but the effective throughput decreases.

High level of overhead is an issue in Ad hoc networks because the nodes mobility causes an increase in control routing operation. When the nodes move, the end-to-end path changes frequently and the network must recreate the network topology again.

This proposal measures some indicators and their impact on the network for several ad hoc routing protocols. Metrics are grouped in two approaches, reliability and overhead. Throughput, dropped packets, jitter, and end-to-end delay are elements of the reliability approach. Cumulative overhead and the overhead behavior are elements of the overhead set approach.

The paper is organized as follows. In Section 2, related works are revised. Section 3 describes the impact of the overhead over AODV, BCHP, and DSDV routing protocols. Experimental results are reported in Section 4 and conclusions are drawn in Section 5.

2. State of the art

Ad hoc routing protocols, generally, can be categorized into proactive, reactive, and cluster protocols. Proactive routing protocols generate the end-to-end path before the packets are transmitted. Each node maintains one or more routing tables to store path information. Topology changes are propagated from each node to all nodes in the network. Examples of these protocols are DSDV (Perkins and Bhagwat, 1994) and OLSR (Clausen, T., & Jacquet, P, 2003).

Reactive routing protocols generate on demand the path between a source and a destination for each packet to be transmitted. Routes are created only when the source node needs to send information. The path needs to be constantly updated until the destination node becomes inaccessible or the path is not necessary anymore. Examples of these protocols are DSR (Boppana and Mathur, 2005) and AODV (Perkins and Royer, 1997).

A hybrid routing protocol shares reactive and proactive protocols characteristics. Cluster routing protocols, a kind of hybrid protocols, group the nodes geographically in a named set cluster. The cluster tries to isolate the broadcast traffic of the nodes belonging to it. Each cluster generally has a cluster head node, responsible for the intercluster communication, named gateway node. The set of head nodes comprises a backbone. Cluster routing protocols in general have the following phases: 1) cluster formation, 2) cluster head election 3) cluster maintenance. Examples of these protocols are CBRP (Jiang, 1999) and BCHP (Torres et al., 2012).

In all routing protocols, route discovery is the most critical task. If there are many path failures in route discovery, the routing overhead is increased, affecting to both, the packet delivery ratio and the delay, according to Zhang et al., (2013). Therefore, the overhead is different for proactive, reactive and cluster protocols (Singh et al., 2016). In proactive protocols, the flooding is the discovery technique and a periodically routing information exchange is mandatory (Paul, 2016). Moreover, due to the node mobility, the periodic update time must be the smallest possible. In reactive protocols, generally, the level of overhead depends on some factors like the information exchange load or the number of connections. In cluster protocols, traffic isolation allows having better overhead values (Alnabhan et al., 2017) (Narayana et al., 2016).

3. Overhead impact

There are some authors that had studied the overhead effect in MANET, for example, Timo and Hanlen (2006) develop fundamental limits on the overhead requirements of routing protocols applying principles from the Information Theory.

Research in La and Seo (2011) determines the minimum length of overhead based on the number of nodes with a flat geographical routing protocol. Besides, it determines the expected overhead and the minimum expected overhead. Tran et al., (2015) quantify overhead for reactive routing protocols with network mobility and traffic load parameters. The same authors, in Tran and Dadej (2014), quantify the overhead for proactive routing protocols with the same parameters used for reactive routing protocols. They conclude that, to reduce overhead and save bandwidth, the Time to Live of cached routes in reactive routing protocols, and, Time-slot for periodical updates in proactive routing protocols, must be the smallest possible.

In cluster protocols, the traffic isolation permits to have better overhead values (Alnabhan et al. 2017) (Narayana et al., 2016).

We have selected AODV for reactive protocols, BCHP for cluster protocols and DSDV for proactive protocols. Each protocol is analyzed based on its properties and routing strategies by determining their overhead impact on the network. Then, specific researches related with overhead impact for each type of MANET protocols are listed.

AODV protocol uses route discovery for path creation process. AODV route discovery is used when any route to destination is found by a node. When a node needs to send information and a route is not available, AODV uses route request (RREQ), route reply (RREP), and router error (RERR) messages. AODV tries to minimize the overhead using destination sequence numbers and RREP to RREQ from intermediate nodes with updated routes to the receiver node.

BCHP protocol varies the overhead level depending on its phase or status. In the Node Initialization phase each node obtains a metric as a function of context characteristics: node speed, node location inside the cluster, and battery power status. This metric, in conjunction with the UNDECIDED state, is sent to its neighbors using HELLO broadcasting messages. In the Cluster Formation, if a node receives several HELLO messages from its neighbors, it proceeds to update its table of neighbors, including each neighboring node identification, link type, metric, and state. Each node reviews its neighbor table, and the node with the best metric becomes the cluster head, the one with the second lowest metric becomes the backup cluster head, and the remaining nodes change their status to managed node. The HELLO messages are used with the Discovery of the Adjacent Cluster phase and the Cluster Maintenance strategy.

In DSDV protocol, all nodes share their network tables periodically. The overhead in DSDV is caused for using updates. DSDV proposes two types of updates, “full dump” and “incremental updates”; the full dump updates are used especially when a high node mobility is present; in these updates, nodes share all their network table information. Incremental updates only use new records of the network table information for the control data interchange.

This research gives a new and interesting framework for the overhead analysis because it obtains the relationship between the overhead and the protocol reliability or efficiency.

4. Methodology

Network Simulation is used for the generation of a set of experiments. The parameters for the initial setup of each experiment are listed on the *Table 1*.

Table 1. Simulation parameters.

Parameter	Values
Protocols	AODV, BCHP, DSDV
Number of nodes	10, 20, 40, 60, 80
Number of connections	20
Area	1Km x 1Km
Simulation time	200 seconds
Mobility model	Two Way
Traffic transport layer	Constant bit rate (CBR)

Two important and related approaches are considered, the first one contains metrics related to the overhead and the second one contains metrics related with the protocol efficiency. On the overhead approach the cumulative overhead for each scenario and the overhead during the simulation time are obtained. Cumulative overhead and overhead in time metrics let to obtain an overall knowledge of how many packets in the routing level are necessary to deliver application packets. The reliability approach is measured across four indicators: dropped packets, jitter, end-to-end delay, and cumulative ratio applications packets. It is important to relate the overhead with the protocol reliability or protocol efficiency. It is possible that the protocol has a high overhead level but could be more efficient. In this case the overhead helps to improve the payload delivered.

5. Results

5.1 Overhead approach

Cumulative overhead: Figure 1 shows the cumulative overhead for each scenario. All the generated routing packets and received application packets for each scenario are related between them. This ratio shows how many routing packets are necessary to deliver application packets. High values imply more routing packets are used; therefore, the overhead level is bigger. AODV has the worst overhead due to its reactive nature. Consequently, each time the information is sent from a source to a destination, control information has to be generated to discover the route tables. Therefore, as long as the nodes increase in the network, a higher amount of overhead is required. In general, DSDV is better than BCHP. Since BCHP is hybrid, it generates control information for both to find the route and for clusters maintenance processes.

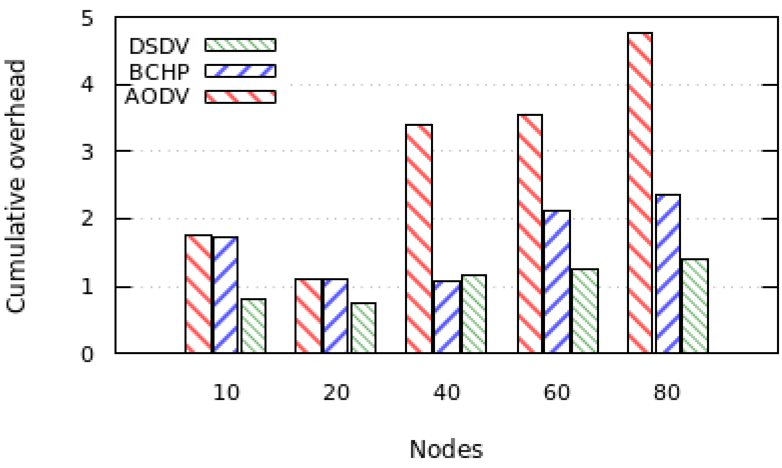

Figure 1. Cumulative overhead

Overhead behavior: Figure 2 shows the ratio between the packets sent by the routing layer and the received application packets for each scenario during the simulation time. The simulation time of the network comprises the initial flooding time of the network that is used in the discovery processes and the nodes initiation. The stabilization time increases proportionally with the increase of nodes in the network. In all cases, the number of required routing packets is greater than the quantity of delivered application packets. In addition, if the number of nodes increases then the overhead increases in the same proportion. AODV has the worst delivered application packets rate. BCHP and DSDV have the best relationship between application data and routing data packets.

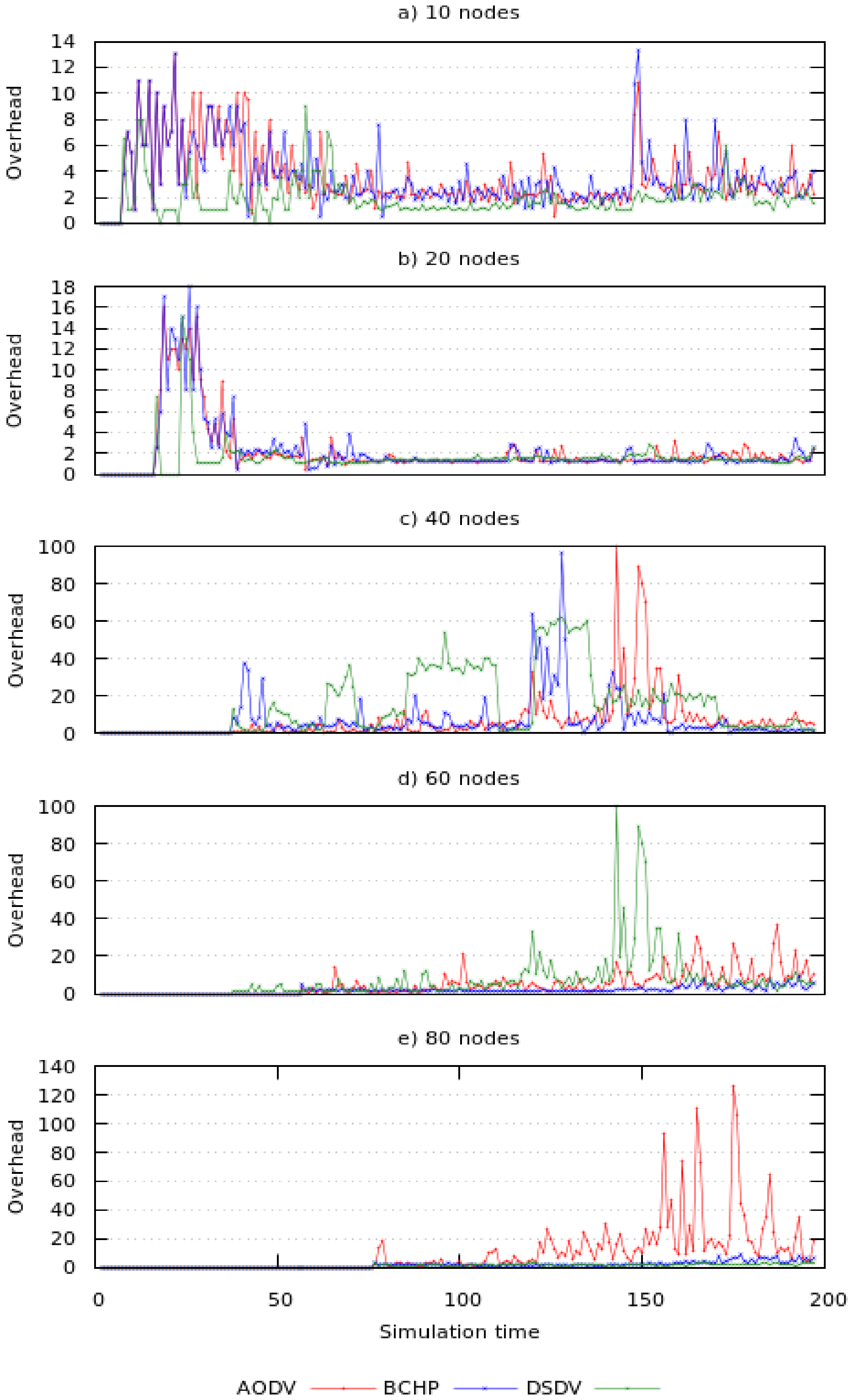

Figure 2. Overhead in time.

5.2 Reliability approach

Dropped packets: Figure 3 shows how many packets (routing or application packets) have been deleted by the routing layer during the simulation time for each scenario. Nodes drop packets due the following reasons: 1) the buffer is full (ifqueue), 2) the link goes down (link failure), 3) the time for acknowledgement packet reception has expired (timeout), 4) time to live value becomes zero (expired TTL), 5) the node has not an entry for the destination network in its routing table (No route). In DSDV protocol, link failure is the first reason to drop packets. In general, BCHP protocol has lower number of dropped packets than the other protocols. In addition, in the BCHP the timeout is the main reason to delete packets. In other hand, the sources of AODV dropped packets are the TTL expired and the link failure, due to the movement of nodes and its reactive behavior.

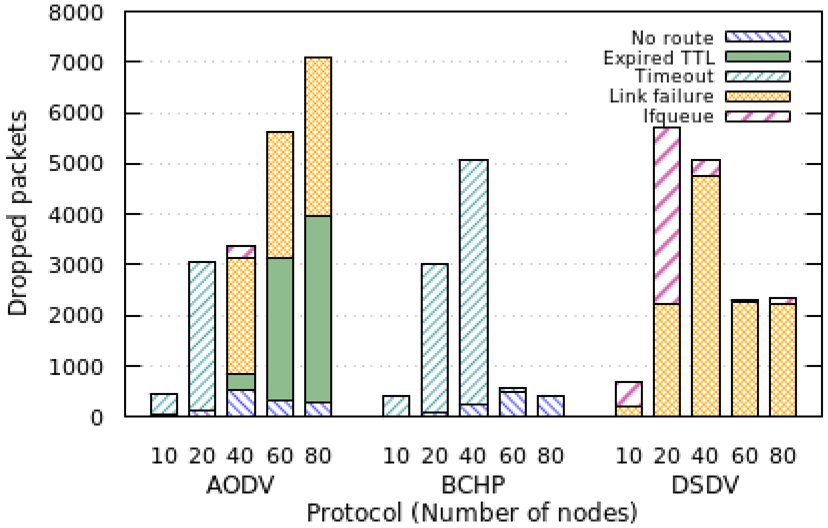

Figure 3. Dropped packets.

Jitter: It is an important indicator especially when multimedia traffic is present because of user experience requirements. Multimedia traffic needs to use the maximum bandwidth; in this case the overhead must allow using the communication channel without unnecessary control data. The *Figure 4* shows that AODV has the worst jitter average. On the other hand, DSDV according to its proactive operation has the best behavior.

Delay Average: The tests use Constant bit rate traffic (CBR) for transport layer, CBR is similar to UDP. In CBR does not exist acknowledgment packets nor retransmissions packets. Delay is related with the communication delay channel. The *Figure 5* shows the average end to end delay for each scenario. AODV generally has the worst delay values in all scenarios. Packets using the BCHP protocol are delivered faster in comparison with the other protocols.

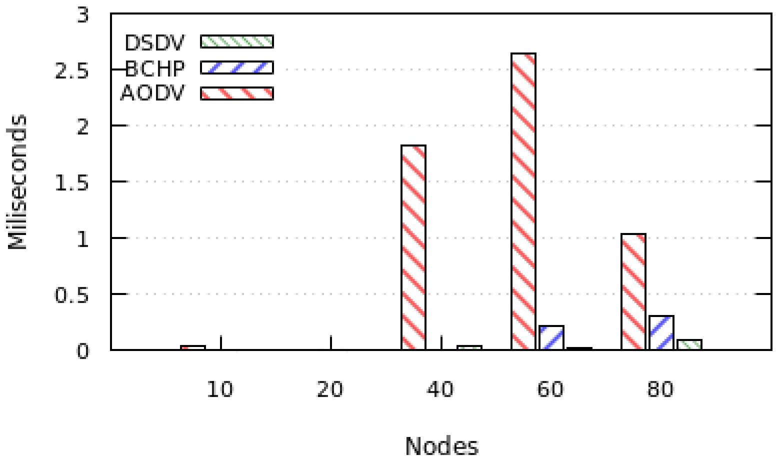

Figure 4. Jitter average.

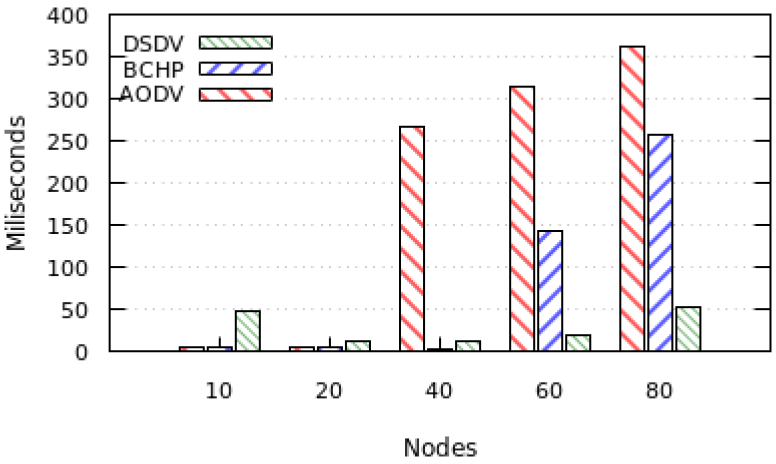

Figure 5. Delay average.

Cumulative ratio application packets: Figure 6 depicts the effectiveness in terms of the ratio between all sent packets versus the received packets belonging to the application layer. It is a measure of how many application packets are generated and how many are received. It is important that this value must be as small as possible. In almost all cases, BCHP shows the best ratio. In other words, BCHP is the most effective because it delivers more application packets than other protocols. BCHP does not saturate the network because the control traffic is concentrated in the cluster. This means, that application packages, in general, will have greater opportunity to reach the destination.

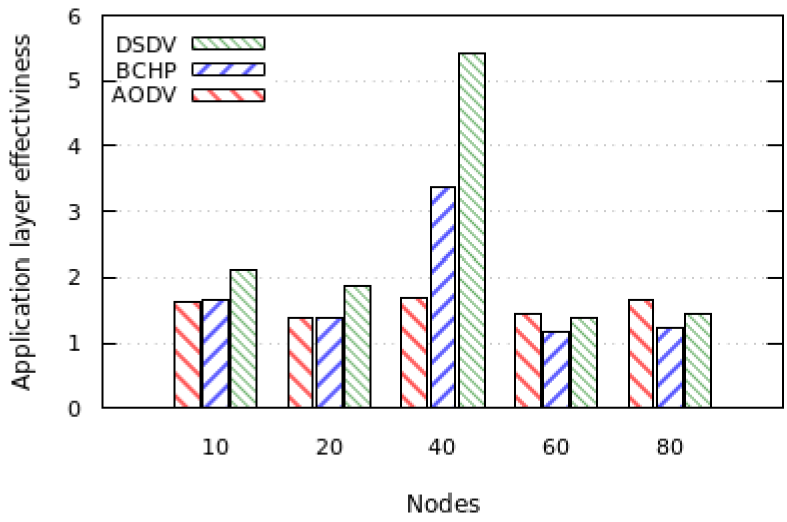

Figure 6. Ratio application packets.

4. Conclusions

The overhead and its relationship with the effectiveness of mobile routing protocols have been analyzed. Research shows that the overhead in all protocols is always greater than the delivered application packets.

DSDV has the best level of overhead but its effectiveness is less than BCHP. BCHP shows the best relationship between overhead and effectiveness. On the other hand, AODV uses the capacity of communication channel in the best way, but it does not have the same effectiveness than BCHP. Therefore, BCHP is the best protocol when the overhead and effectiveness approaches are analyzed in each scenario.

Based on this research, in the future, we are looking for the best Ad hoc routing cluster protocol with the aim to develop a new protocol that decreases the overhead and increases the effectiveness.

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