A new way of achieving multi-path routing in wireless networks

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Abstract: In the 21st century, the wireless technology is still developing rapidly and trying to be 'Faster, Higher, and Stronger': faster data rate, higher bandwidth and stronger connectivity. Wireless Mesh Networks (WMN) have been envisioned as an important solution to the next generation wireless networking which can be used in wireless community networks, wireless enterprise networks, transportation systems, home networking and last-mile wireless internet access. They also provide a cheap, quick and effective way for building wireless data networks. Considering the nature of these networks, routing is a key process for operating the WMN. This paper proposes a new way of creating multi-path routing protocols based on a fusion between multicast and unicast routing protocols to get different routes (node-disjoint or link-disjoint) from the source to its destination. The simulation results using Network Simulator 2 (NS-2) show that our new Multi-path Routing Protocol (Fusion) outperforms Ad hoc On-Demand Distance Vector (AODV) and Ad hoc On-demand Multi-path Distance Vector (AOMDV) routing protocols in terms of average network throughput, end-to-end delay, and number of flows.

Keywords: wireless mesh networks; routing; multi-path routing protocols; multicast and unicast routing protocols; throughput; end-to-end delay.

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1 Introduction

The great success of wireless networks during recent years is mainly due to the low cost of hardware, the broadband, the simplicity of implementation, and the robustness comparable to wired networks. Nowadays, the most deployed Wireless Local Area networks (WLAN) are based on the IEEE 802.11 standard (Institute of Electrical and Electronics Engineers). Two configurations are possible: ad hoc and infrastructure modes. Mesh networks are built upon a mix of fixed and mobile nodes interconnected via wireless links to form a multihop ad hoc network. Unlike pure Mobile Ad hoc Network (MANETs), a mesh network introduces a hierarchy in the network architecture by adding dedicated nodes (called mesh routers) that communicate wirelessly to construct a wireless backbone (Conti and Giordano, 2007; Akyildiz et al., 2005). The wireless mesh networks are the ideal solutions to provide both indoor and outdoor broadband wireless connectivity in urban, suburban, and rural environments without the need for extremely costly wired network infrastructure. Routing protocols are used to discover and maintain routes between the source and destination nodes. For MANET and mesh networks, there are two main kinds of routing protocols: on-demand protocols (also called reactive protocols) and table-based protocols (also called proactive protocols).

For reactive protocols, nodes only compute routes when they are needed (Saranya et al., 2015). Usually, caches are used to reduce the effort of route discovery. The Dynamic Source Routing (DSR) (Johnson et al., 2007) is designed for use in the wireless environment of an ad hoc network, when a node S originates a new packet destined to some other node D, it places in the header of the packet a source route giving the sequence of hops that the packet should follow on its way to D, this mechanism is called source routing.

The Ad Hoc On-Demand Distance Vector (AODV) routing protocol (Perkins et al., 2003) is a reactive routing protocol based on Dynamic Destination Sequenced Distance Vector (DSDV) (Perkins and Bhagwat, 2001) (Dynamic Destination Sequenced Distance Vector). AODV uses a broadcast route discovery mechanism and uses hop-by-hop routing by maintaining routing table entries at intermediate nodes.

For proactive protocols, each node maintains a routing table containing routes to all nodes in the network (Saranya et al., 2015). Nodes must periodically exchange messages with routing information to keep routing tables up-to-date. Dynamic Destination Sequenced Distance Vector Routing (DSDV) tries to keep the simplicity of Distributed Bellman-Ford routing (Perkins and Bhagwat, 2001) and avoid the looping problem by tagging each routing table entry with a sequence number.

In Clausen and Jacquet (2003), a proactive routing protocol, called Optimised Link State Routing (OLSR) for MANET is proposed. The protocol inherits the stability of the link state algorithm. Owing its proactive nature, it has an advantage of having the routes immediately available when needed. OLSR is an optimisation of a pure link state protocol for MANET. First, it reduces the size of control packets: instead of all links, it declares only a subset of links with its neighbours who are its multipoint relay selectors. Secondly, it minimises flooding of the control traffic by using only the selected nodes, called Multipoint Relays (MPR), to diffuse its message in the network. This technique significantly reduces the number of retransmissions in a flooding or broadcast procedure.

At the moment, there are two protocols mainly discussed on the Internet Engineering Task Force (IETF) standard track:

- Dynamic MANET On-demand (DYMO) (Chakeres and Perkins, 2010) routing is a successor to AODV. Therefore, it shares the reactive feature of its ancestor. Compared to AODV, DYMO has a TLV structure (Type-Length-Value) that allows extensibility and permits a route to be improved by changing in response to superior routing information.
- OLSRv2 (Clausen et al., 2011; Clausen et al., 2014) is the successor of OLSRv1. Being modular by design, OLSRv2 is made up from a number of generalised building blocks, standardised independently, and applicable for other MANET protocols. It is simpler and more efficient than OLSRv1.

The protocols mentioned above represent the reactive and proactive protocols respectively in the standardisation of MANET routing protocols. In terms of comparison, the performance evaluation in Hamma et al. (2006) shows that the traffic load, the mobile node mobility, and the network density all have an impact on the performance of the routing protocol. The proactive protocol offers better performances for Constant Bit Rate (CBR) sources given that it guaranties lowest delay and jitter; however it consumes more bandwidth. But, when the mobility is low, the reactive protocol functions are more efficient and achieve a low delay and overhead.

There is a third family called Hybrid Routing Protocols, which try to take advantage of both proactive and reactive protocols. Normally, it uses pro-active discovery within a node's local neighbourhood, and a reactive protocol for communication between these neighbourhoods.

Contrary to uni-path routing protocols (introduced above), multi-path routing protocols try to find multiple routes between a source and a destination node instead of using only one single path by exploiting the density of the network. These multiple paths between source and destination node pairs can be used to compensate for the dynamic and unpredictable nature of ad hoc and mesh networks. The multi-path routing could offer several benefits: load balancing, fault-tolerance, higher aggregate bandwidth, lower end-to-end delay, etc.

Kun et al. (2005), Leung et al. (2001), Lee and Gerla (2001) and Pearlman et al. (2000) agreed that multi-path routing is a promising technique that solves the non-equal traffic repartition, increases throughput, and offers a faster data rate but it suffers from many problems such as the following.

Number of paths depends mostly on the density of the network (especially source and destination neighbours). Routes that look independent in a point of view graph cannot be always the case in point of view radio like two nodes in two different paths, but in the same transmission range which causes the occupation of the medium by one node at a time, and resulting in the non-use of the different paths simultaneously. Not all paths founded by the source are optimal; the single path protocols can be more effective because adding other paths can result in significant delay.

Finally, we noticed that to create a multi-path scheme the source node must initiate a route discovery, decompose, and send the data packets according to number of paths found to destination, monitoring all paths in case of a link failure while looking for new better routes. All of that can cause a significant latency at source node level.

In this paper, we focus on this last problem and try to minimise the tasks on the source in a session between two nodes by creating a new way of multi-path routing and establishing secondary source nodes that help in sending data to destination.

The remainder of this paper is organised as follows. Section 2 presents the related work; we are going to introduce several multi-path routing protocols that have been proposed in the literature. Section 3 describes the proposed contribution for multi-path routing and Section 4 presents simulation results. Finally, Section 5 concludes the paper and gives some future works.

2 Related works

Multi-path routing involves considering not a single route between a source and a destination for the data transmission, but a set of paths. It is a routing technique that is based on multiple paths and can serve three main purposes (Mueller et al., 2004; Doghri, 2012):

- *Fault tolerance*: Fault tolerance can often be achieved via two approaches, such as sending redundant packets on multiple paths or setting up one or more backup paths in advance in case of route failure.
- *Traffic load balancing*: Traffic load balancing is the efficient use of available resources in the network. Several studies have shown that data distribution from one stream over multiple paths, instead of conveying the flow on one path, could reduce congestion and bottlenecks (Ktari et al., 2006; Doghri, 2012).
- *Increase offered bandwidth to a stream*: A routing that is based on a "multiple path" strategy can offer an aggregate bandwidth, via the different paths used in parallel, which is larger than the bandwidth offered by a single path. This can help meet the bandwidth requirements of an application that might not have been satisfied with the use of a single path with limited bandwidth.

Multi-path routing is based on three mechanisms: path discovery is the process of finding multiple paths between two nodes road maintenance consists of repairing broken roads by looking for new, valid roads, and traffic allocation decides how the data to be transmitted will be distributed over the available paths between a source and a destination in the network.

In the following, we are going to introduce several multi-path routing protocols that have been proposed.

Alternative path routing: In Pearlman et al. (2000), Alternate Path Routing (APR) is proposed. APR has its origins in the traditional circuit-switched telephone networks, where it reduced call blocking by providing multiple network routes for the initial call-setup messaging. The potential benefits of APR make it appear to be an ideal candidate for the bandwidth limited and dynamic mobile ad-hoc networks. The investigation of APR in the MANET environment has revealed that APR can, in some circumstances, provide notable improvements to end-to-end capacity. Quite often, however, the network topology and channel characteristics limit what APR is able to achieve.

Ad hoc on-demand multi-path distance vector routing: AOMDV (Marina and Das, 2006) is an on demand, multi-path distance vector routing protocol for mobile ad hoc networks. It extends the AODV protocol to compute multiple disjoint loop-free paths in a route discovery. AOMDV relies as much as possible on the routing information already available in the underlying AODV protocol, and searches for multiple paths with disjoint links. Among the multiple paths found, AOMDV uses only the best (lowest) number of hops count for the data transmission between a source and a destination. The other calculated paths could be used only when the main route is broken (the route becomes invalid) (Doghri, 2012). AOMDV is based on two mechanisms: a path update rule to maintain multiple paths without loop routing, and a distributed mechanism between the different nodes of the network to calculate disjoint paths, thereby limiting the overhead incurred in discovering multiple paths. In particular, it does not employ any special control packets. In fact, extra RREPs (Route REPly

Packets) and RERRs (Route ERRor Packets) for multi-path discovery and maintenance along with a few extra fields in routing control packets (i.e., RREQs (Route REQuest Packets), RREPs, and RERRs) constitute the only additional overhead in AOMDV relative to AODV.

Split multi-path routing: Lee and Gerla (2001) proposed an on-demand routing scheme called Split Multi-path Routing (SMR) that establishes and utilises multiple routes of maximally disjoint paths. Providing multiple routes helps minimising route recovery process and control message overhead. The main goal of SMR is to build maximally disjoint multiple paths. It is necessary to construct maximally disjoint routes to prevent certain nodes from being congested, and to utilise the available network resources efficiently.

The destination must know the entire path of all available routes so that it can select the routes. The source routing approach is used. In the normal source routing approach, the duplicate RREQ packets are discarded. This may cause the multi-paths to be mostly overlapped.

OLSR-based multi-path routing: the APR and AOMDV are mainly based on reactive topology discoveries. In the literature there are also some routing mechanisms proposed based on a proactive approach. Viennot and Jacquet (2007) proved that for OLSR, the broadcasting mechanism based on MPR (MultiPoint Relays) is necessary and sufficient to provide multiple connections between the source and destination. Therefore, several protocols based on OLSR are introduced such as Source Routing OLSR; Kun et al. (2005) propose a version of multi-path OLSR using IP source routing. Based on Dijkstra algorithm, the node calculates multiple paths to the destination. The calculated paths are strictly node-disjoint. The path is inserted in the IP header of the packet before sending it. Based on these multiple paths, the paper introduces an algorithm of load balancing to transmit data through the paths based on the congestion information of all the intermediate nodes on each path. Strict node disjoint routes are not always necessary and the suppression of nodes in multiple calls of the Dijkstra algorithm could not work for sparse networks. The node-disjoint multiple paths are not suitable for partition or fusion group of nodes that can temporarily imply a single link for connection.

Multi-path dynamic source routing: the MP-DSR protocol (Leung et al., 2001), based on DSR (Johnson et al., 2007), looks for multiple paths from the source to the destination, taking into account a quality of service metric, namely end-to-end reliability. The end-to-end reliability is defined as the probability of having a successful transmission between two nodes in the network during a given period. The reliability of a path depends on the availability of the links that constitutes this path. The availability of a link is defined as the probability that a link exists within a given time period. Leung et al. (2001) did not propose a technique to measure the link availability between a node *x* and another node *y*. They assume that it is locally known information (*Ax*; *y* (*t*) corresponds to the availability of the link (*x*; *y*)) for a *t* period. The reliability of the *k*-th path between a source S and a destination D, denoted $\prod_{s;d}^{k}(t)$, is the product of links availability *Ax*; *y* (*t*) between each pair of intermediate nodes (*x*; *y*) for a *t* period.

To cope with the issues stated above, we propose a new way to provide a better MPR between the source and the destination. The proposed method is detailed in the next section.

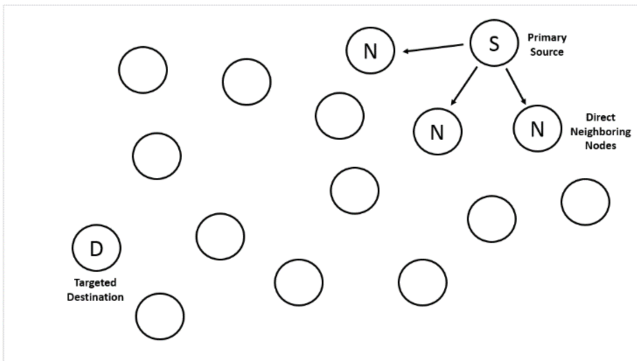
3 Proposed mechanism

In this section, we describe our proposition. In order to decrease end-to-end delay and increase throughput, the proposed solution aims to create a multi-path routing out of a fusion between a multicast and unicast protocols. We have noticed in the most of works done and the contributions regarding multi-path routing (Tsai and Moors, 2009; Krishnan and Silvester, 1993) that researchers tried to achieve multi-path schemes basing on the unicast routing protocols (based on the concept of keeping all the paths found on the root discovery phase (Marina and Das, 2006)). This requires a high rate of control packets, and extra work to be done at source level, congestion, network resources consumption, etc.

In our new approach, we propose:

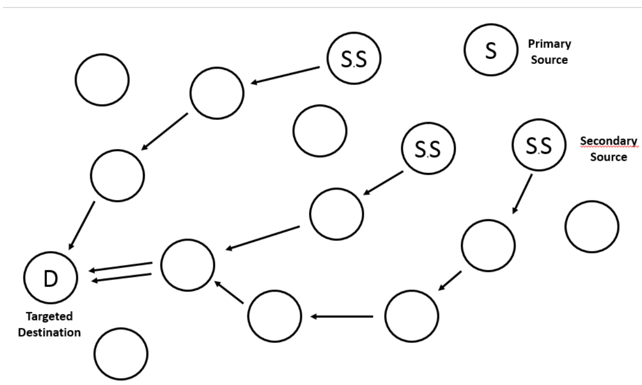
First, to rely on a multicast protocol in the primary source level and the multiple destinations of the multicast session would be the direct neighbouring nodes to the primary source, (see Figure 1).

Figure 1 First phase (multicast session)



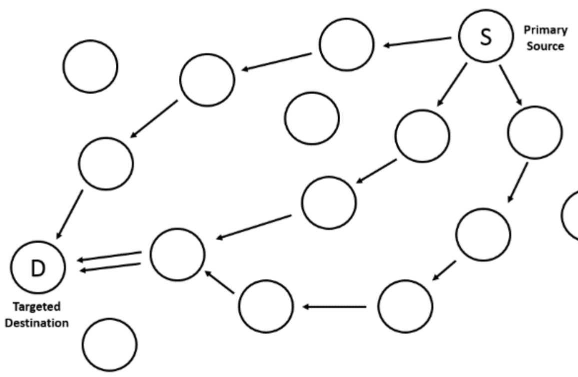
Afterwards, every destination node becomes a source node (secondary source) that works independently from each other, and a unicast protocol is applied to forward data received from the primary source to the target destination as illustrated in Figure 2.

Figure 2 Second phase (unicast session)



At last, the fusion between those two sessions gives us a multi-path routing scheme from the primary source to the targeted destination (see Figure 3).

Figure 3 Result of the fusion (a multipath scheme)

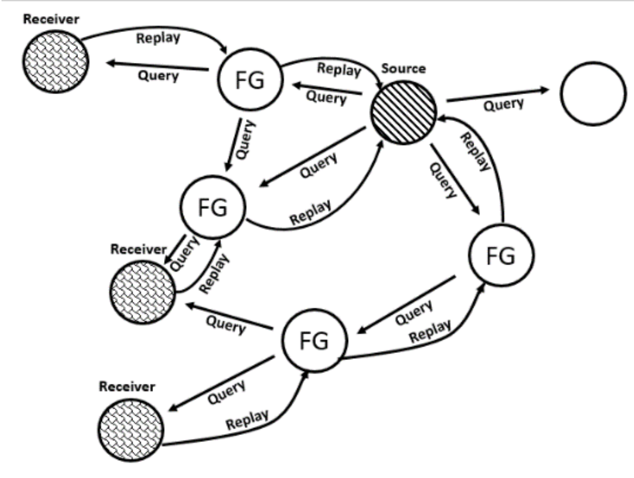


In what follows, we focus on how we manage to create a fusion between a multicast and unicast protocols, in our implementation we have used for multicast routing: Multicast Ad hoc On-Demand Distance Vector (MAODV) routing protocol (Zhu and Kunz, 2004), and AODV (Perkins et al., 2003) for unicast routing.

MAODV (Royer and Perkins, 2000) routing protocol discovers multicast routes on demand using a broadcast route-discovery mechanism. A mobile node originates a Route Request (RREQ) message when it wishes to join a multicast group, or when it has data to send to a multicast group but it does not have a route to that group. Only a member of the desired multicast group may respond to a join RREQ. If the RREQ is not a join request, any node with a fresh enough route (based on the group sequence number) to the multicast group may respond. If an intermediate node receives a join RREQ for a multicast group of which it is not a member, or if it receives a RREQ and it does not have a route to that group, it rebroadcasts the RREQ to its neighbours. As the RREQ is broadcasted across the network, nodes set up pointers to establish the reverse route in their route tables. A node receiving a RREQ first updates its route table to record the sequence number and the next hop information for the source node. This reverse route entry may later be used to relay a response back to the source. For join RREQs, an additional entry is added to the multicast route table. This entry is not activated unless the route is selected to be part of the multicast tree. If a node receives a join RREQ for a multicast group, it may reply if it is a member of the multicast group's tree and its recorded sequence number for the multicast group is at least as great as that contained in the RREQ. The responding node updates its route and multicast route tables by placing the requesting node's next hop information in the tables, and then unicasts a Request Response (RREP) back to the source node. As nodes along the path to the source node receive the RREP, they both add a route table and a multicast route table entry for the node from which they received the RREP, thereby creating the forward path. The first member of the multicast group becomes the leader for that group. The multicast group leader is responsible for maintaining the multicast group sequence number and broadcasting this number to the multicast group. This is done through a Group Hello message. The Group Hello contains extensions that indicate the multicast group IP address and sequence numbers (incremented every Group Hello) of all multicast groups for which the node is the group leader. Nodes use the Group Hello information to update their request table (see Figure 4). For further details, see (Royer and Perkins, 2000).

In our case, MAODV is responsible only for establishing a multicast session between the primary source as a group leader and its direct neighbouring nodes (one hop) as the multiple destinations, and the round robin strategy (Nasipuri et al., 2001) to decompose data packets then send it.

Figure 4 Example of a multicast tree with MAODV



The Ad-Hoc On-Demand Distance Vector (AODV) routing protocol is described in RFC 3561 (Perkins et al., 2003). The philosophy in AODV, like all reactive protocols, is that topology information is only transmitted by nodes on-demand. When a node wishes to transmit traffic to a host to which it has no route, it will generate a RREQ message that will be flooded in a limited way to other nodes. This causes control traffic overhead to be dynamic and it will result in an initial delay when initiating such communication. A route is considered found when the RREQ message reaches either the destination itself, or an intermediate node with a valid route entry for the destination. AODV defines three types of control messages for route maintenance:

- *RREQ*: A node requiring a route to a node transmits a route request message. As an optimisation, AODV uses an expanding ring technique when flooding these messages. Every RREQ carries a Time-To-Live (TTL) value that states for how many hops this message should be forwarded. This value is set to a predefined value at the first transmission and increased at retransmissions. Retransmissions occur if no replies are received. Data packets waiting to be transmitted (i.e., the packets that initiated the RREQ) should be buffered locally and transmitted by a FIFO principle when a route is set.

- *RREP*: A route reply message is unicasted back to the originator of a RREQ if either the receiver is the node using the requested address, or it has a valid route to the requested address. The reason one can unicast the message back, is that every route forwarding a RREQ caches a route back to the originator.
- *RERR*: Nodes monitor the link status of next hops in active routes. When a link breakage in an active route is detected, a Route Error (RERR) message is used to notify other nodes of the loss of the link. In order to enable this reporting mechanism, each node keeps a "precursor list", containing the IP address for each its neighbours that are likely to use it as a next hop towards each destination (see Figure 5). For more details, see (Perkins et al., 2003). In our case, AODV is used to connect the secondary sources (multicast destinations) to the targeted destination, and forwarding the received data from the primary source to the targeted destination.

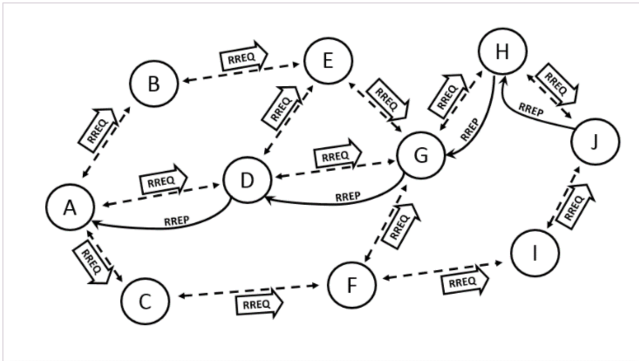
The following algorithm illustrates the whole fusion process:

Algorithm: Multi-path routing based fusion

```
Input: Primary source, target destination
Initialisations:
   Set PS          /*Primary source*/
   Set MD          /*Multicast destinations*/
   Set SS          /*Secondary source*/
   Set TD          /*Targeted destination*/
   Set SSc TO 0    /*a counter for SS numb/
Begin
   PS = group multicast leader
   /*Source start multicast session with all one
         hope neighbouring nodes */
   While (PS.OneHope == true) {
        Join multicast group
        MD = PS.OneHope }
   /*multicast destinations became secondary
          sources */
   SS = MD
   /*and seek a unicast rout to targeted
          destination*/
   While (!SS) {
        SS.Connect TO TD
        SSc = SSc + 1}
    /*when data packets received from PS at
           MD they are forwarded to TD*/
    For i ← 1, SSc Do
        If ((PS.SendDataPacket == true) &&
     (MD.ReceivedDataPacket == true)) Then
                SS.ForwardDataPacket TO TD
        EndIf
    EndFor
End
```

With our fusion, we have succeeded to apply MPR on a mesh network topology using a unicast and a multicast protocol. Therefore, using the proposed mechanism for n multicast protocols and m unicast protocols, our mechanism could generate up to $n \times m$ multi-path protocols ($n*m$: possible fusion), so it takes a good use and benefit from previous work (reuse of the existing protocols). This presents the most important advantage of our proposition especially the number of options that it offers not only for ad hoc, but for all types of networks like WSN, infrastructure networks, VANET, etc.

Figure 5 An example of creating a route with AODV



4 Simulation and results

We use NS2 simulator because it is an effective simulation tool and an open source software; it is the most used simulator for studies on mobile ad hoc networks. So it plays an important role in the research community of mobile ad hoc networks to evaluate the performance of our proposed solution. The simulation compares AODV (the unicast protocol) and AOMDV (the multi-path extension for AODV) with our solution. This simulation uses three parameters:

- *Throughput*: It is defined as the actual number of bits that flow through a network connection in a given period of time.
- *End-to-end delay*: It refers to the time taken for a packet to be transmitted across a network from a source to a destination. This includes all possible delays caused by buffering during route discovery latency as well as queuing at the interface queue.
- *Packet delivery ratio*: It is defined as the ratio of data packets received by the destinations to those generated by the sources.

Furthermore, we define two scenarios: the first one is based on network size and the second one is based on number of flows. The simulation parameters are given in the Table 1.

4.1 First scenario: based on network size

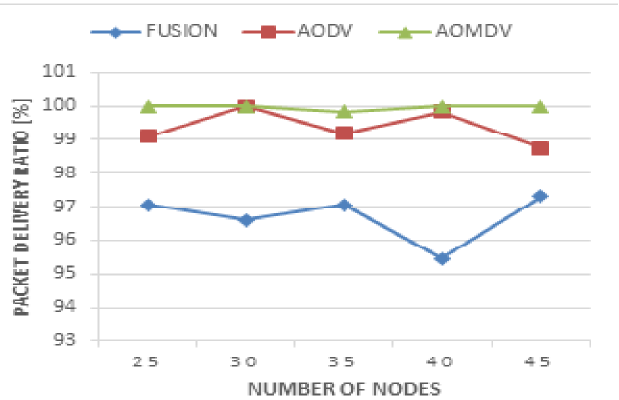
In this scenario, we assumed that two CBR flows exist in the grid mesh network topology. The network size increases from 25 to 45 nodes. The average results of packet delivery ratio, end to end delay, and throughput are plotted in the graphs Figures 6 to 8.

Table 1 Simulation environment

Parameter	*Value*
Channel type	Channel/Wireless channel
Radio-propagation model	Propagation/Two ray round
Network interface type	Phy/WirelessPhy
MAC type	Mac/802.11
Interface queue type	Queue/Drop Tail
Link layer type	LL
Antenna	Antenna/OmniAntenna
Maximum packet in ifq	50
Packet size	1000 bytes
Area (m × m)	1000 × 1000
Source type	UDP (CBR)
Simulation Time (sec)	310
Routing protocol	Fusion, AODV, AOMDV
Network device	Single interface single channel
Traffic type	CBR
Flows number of scenario 1	2
Flows number of scenario 2	1, 2, 3, 4, 5
Network size of scenario 1	25, 30, 35, 40, 45
Network size of scenario 2	35

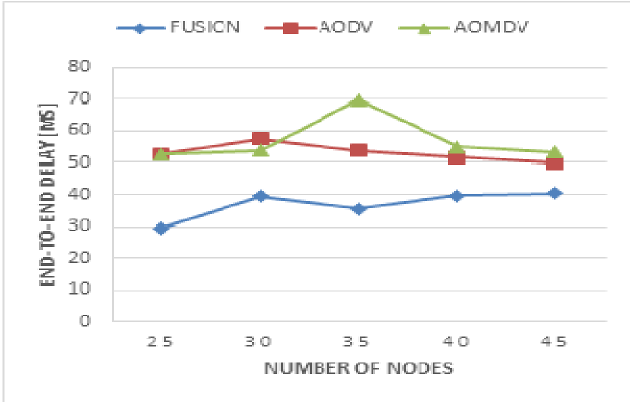
Figure 6 shows that the packet delivery ratios of the three different protocols (Fusion, AODV and AOMDV) are above 95%, which proved the low number of dropped packets in the network. This is because there are only two flows (two sources, two destinations) in the network, and the number of nodes keep rising, which offer routes that are more efficient.

Figure 6 Packet delivery ratio and network size



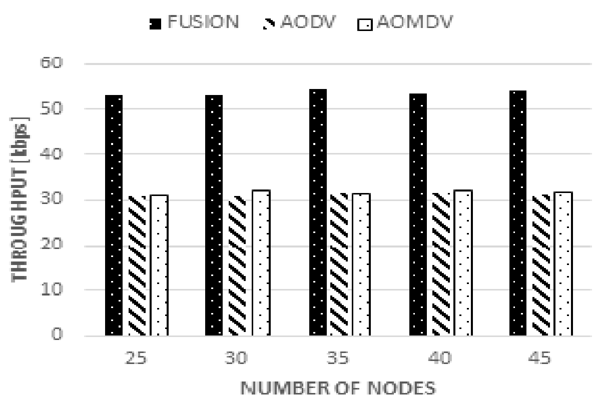
When considering the end-to-end delay, the Fusion protocol decreases it by approximately 15 ms because it uses more than one route simultaneously to deliver packets and decomposes the tasks on primary source level, which provides a better average end-to-end delay than AODV and AOMDV protocols. When the network size is about 35 nodes, AOMDV reaches a significant delay of 6978 ms to send packets due the reselection of better route between the source and the destination, which causes an extra delay. Figure 7 illustrates this result.

Figure 7 End-to-end delay and network size



The average throughput achieved using Fusion protocol is increased by + 20 kbps thanks to using several routes simultaneously, which aggregates throughput in routes used in the corresponding process. As a consequence, we obtain with the Fusion protocol better throughput than with AODV and AOMDV protocols. Furthermore, we can observe that the value of the throughput for the three protocols has slightly changed, mostly because the number of flows was fixed for each scenario. Consequently, we have no extra packets to use the bandwidth, leading to non-decreasing or changing throughput value. Figure 8 shows the network throughput results.

Figure 8 Throughput and network size

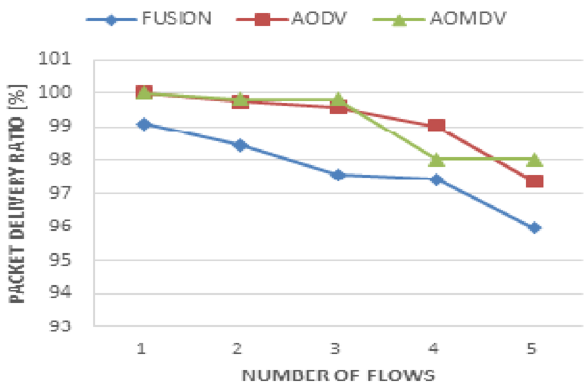


4.2 Second scenario: based on number of flows

In this scenario, we have assumed that the network size is fixed to 35 nodes. The CBR flow increases from one to five. The average results of packet delivery ratio, end to end delay, and Throughput are plotted in the graphs Figures 9 to 11.

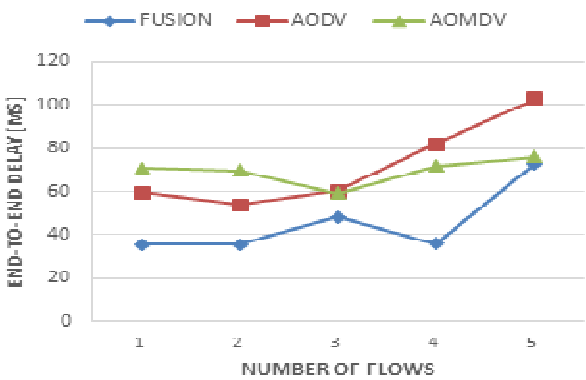
Figure 9 shows the results concerning the packet delivery ratio of the three different protocols (Fusion, AODV and AOMDV). They are above 99% at a single flow, and start to decrease down to 96% by reaching five flows due to the quantity of packets generated (topology and control packets) by Fusion and AOMDV, respectively. Furthermore, AODV gives a better ratio and remains stable because it generates the amount of packets needed to create only a single path to destination (low overhead), until it reaches five flows when it starts to decrease.

Figure 9 Packet delivery ratio and number of flows



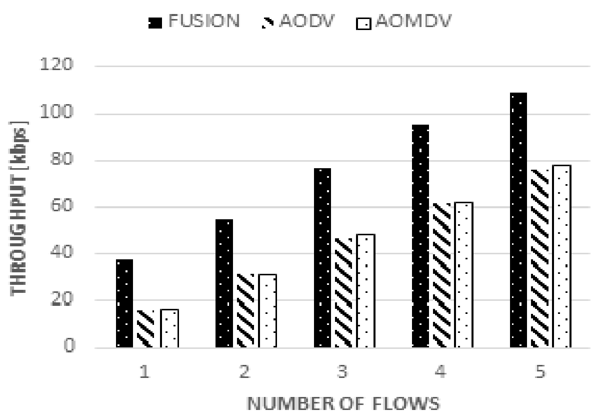
The Fusion protocol end-to-end delay decreases by approximately 20 ms and provides a better average end-to-end delay than AODV and AOMDV protocols. However, when the flows number gets higher, all protocols observed delays get bigger due to buffering during route discovery and queuing at the interface queue. We can also notice that AODV offers less delay than AOMDV while considering up to three flows. Indeed, AODV route discovery ends before AOMDV that needs an extra delay to find other routes to destination. Figure 10 illustrates this result.

Figure 10 End-to-end delay and number of flows



The average throughput achieved using Fusion protocol increased by +25 kbps in comparison to AODV and AOMDV protocols' average throughput. In addition, it keeps rising mostly because the number of flows is augmented, meaning more packets to send and bigger throughput. Figure 11 shows the network throughput results.

Figure 11 Throughput and number of flows



5 Conclusions

In this paper, we have proposed a new way of creating multi-path routing protocols based on a fusion between multicast and unicast routing protocols to get different routes (node-disjoint, link-disjoint or sometimes routes partially disjoints) from the source to the destination to increase the throughput (aggregate bandwidth) and decrease end-to-end delay. The new multi-path routing scheme is implemented by a Fusion between MAODV (Multicast Protocol) and AODV (Unicast Protocol) based on the 802.11 Standard. We have shown the difference between the new multi-path routing scheme and multi-path routing protocols. Simulation results show that Fusion performances compared with AODV and AOMDV is more efficient because it decreases end-to-end delay and increases the network throughput.

We try to use the Fusion protocol at default parameters to evaluate it without any enhancement, so in future works we will add some metrics to our protocol, especially we have the option to add one to enhance the first phase (multicast protocol), and a different one to the unicast phase (unicast protocol). It is also possible to use a different pair of protocols (multicast and unicast) knowing the amount of already existing protocols, to find the optimal couple that meets communication applications requirements.

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