Performance of AODV Routing Protocol enabled by Network Coding

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***Abstract*— The wireless network called mobile ad-hoc network (MANET) is characterized by a lack of fixed routing facilities (e.g. wired networks and access points), with connectivity and routing being instead established through inter-node coordination. Furthermore, in a MANET, many control packets are redundantly transmitted due to signaling and data broadcasting. This study proposes the application of a dominating set and adaptive partial dominating (APDP) approach to current routing protocols like ad-hoc on-demand distance vector (AODV) as a solution to this issue. The creation of new packets through the merging of packets obtained on their incoming margins can be achieved by intermediate network nodes through the novel paradigm of network coding. The present study undertakes an assessment of AODV dominating set performance through the application of DS and APDP based on network coding to AODV, with the overall aim of improving broadcasting, end-to-end delay, network load, and packet latency, as well as ensuring the security of packet transmission.**

Keywords- adaptive partial dominating; dominating sets; AODV; network coding

I. INTRODUCTION

Device mobility has been made possible by mobile IP and wireless networks that can tap into fixed networks. However, this mobility remains subject to some limitations, as connectivity to the core network is required. In this context, the ad-hoc network with a topology that changes fast, known as a mobile ad-hoc network (MANET), has stirred a great deal of interest in recent times. The rapid modifications in the topology of this network are enabled by the high mobility of its nodes, which also demonstrate random dynamic connections.

A MANET constitutes a stand-alone system of mobile nodes [1] that possess wireless transmitters and receivers with omni-directional, highly point-to-point or potentially steerable antenna. An arbitrary, multi-hop graph or ad-hoc network forms between the nodes at a specific point in time, according to how the nodes are positioned, the extent of coverage of their transmitters and receivers, as well as the levels of transmission power and co-channel interference. When the nodes shift their position or modify their transmission and reception parameters, this ad-hoc topology undergoes changes. Dynamic technology of ad-hoc networking is a necessity not just for the future but also for present times. With the expansion of the growing field of mobile and nomadic computing based on mobile IP operation, mobile networking technology capable of high adaptability will be needed for the efficient management of multi-hop, ad-hoc network clusters with stand-alone functioning or attachment to a fixed network.

MANET unicast routing protocols can be proactive or reactive. Proactive routing (e.g. OLSR [21]) is characterised by the fact that the current flow of data does not affect the routing of information amongst the network nodes. The link state protocol OLSR broadcasts link state data via an enhanced broadcast mechanism. On the other hand, in reactive routing (e.g. AODV [3]), identification of routes to destinations is undertaken by the nodes only when necessary. The transmission of a route request (RREQ) message all through the network is the first step of the route identification process and is completed once it is received either by a node with a viable route to the destination or by the actual destination. The next step is the return of a route reply (RREP) message to the source through the same broadcasting path used for the RREQ message. Packets are sent from the source to the destination once the RREP message is received. Another type of protocol, called hybrid protocol (e.g. ZRP [20]) can be obtained through the combination of proactive and reactive protocols. In the hybrid protocol, the closest nodes are typically retained proactively and identification of routes to the rest of the nodes occurring when necessary.

The concept underpinning techniques based on neighbour knowledge involves selection of a few forward nodes to produce a connected dominating set (CDS) based network coding so that flooding of the entire network is prevented. If all network nodes are included in a given set of nodes or abut a node in that set, then that set of nodes is considered to be a CDS. Once this is established, the difficulty is choosing a few forward nodes without reliance on global network information.

The present study undertakes an assessment of network coding enabled AODV dominating set performance through the application of APD to network coding aware AODV, with the overall aim of improving broadcasting, end-to-end delay, network load, and packet latency, as well as ensuring the security of packet transmission. To this end, the study has discussed dominating sets to extract relevant notions of domination in graphs. In the following parts, the study will focus on different aspects. Thus, the second part reviews existing research, while the third part addresses dominating sets and the theory of domination in graphs, in keeping with [9]. The fourth part is concerned with the route request algorithm based on dominant pruning. The fifth part outlines the findings from technique simulation, and finally, the sixth part provides concluding remarks and suggestions for further research.

II. RELATED WORK

There is a number of existing broadcasting methods, which are differentiated by the heuristics used to diminish irrelevant broadcast transmissions. There are four main types of broadcasting protocols [1], as follows:Blind flooding [9]: A packet is not broadcasted more than one time by each network node, as packet transmission to adjacent nodes is triggered by reception of the first copy of the packet.Probability-based techniques [12]: The re-broadcasting of a packet by a node depends of a specific probability *p*. Blind flooding occurs when *p* has a value of one.Area-based techniques [12]: A node relies on packet and neighbour location information to perform packet broadcasting. A packet received by a node from a very close neighbour will only reach the nodes covered by the initial broadcast.

Neighbour information techniques [15]: The topology does not extend beyond two hops of a node, which is called two-hop neighbourhood and means that the node possesses partial topology information. These techniques can be divided into neighbour-designated technique and self-pruning technique. The former is characterised by the fact that the one-hop neighbours designated for packet forwarding are established by the node broadcasting a packet intended for flooding. The latter technique involves direct packet broadcasting by a node and packet forwarding can be decided by every neighbouring node receiving the packet. The neighbour information techniques are considered by Williams and Camp [1] better than other broadcast protocols. Meanwhile, the performance of the basic form of the neighbour-designated technique was demonstrated by Lim and Kim [6] to exceed that of the self-pruning technique. By contrast, the best neighbour-designated technique was indicated by Wu and Dai [7] to have a lower performance compared to an enhanced self-pruning technique, on the basis of partial topology information.

The selection of the forwarding list in neighbour-designated techniques hinges significantly on dominating sets. The formulation of estimations suitable for computation of minimum cardinality CDS (MCDS) has been the focus of ample research. Wan and colleagues [13] have put forth an algorithm with a fixed estimation of eight, but this algorithm is restrictive in that broadcast performance can only be undertaken after the construction of a spanning tree for selection of the dominating or forwarding nodes.

The greedy set cover (GSC) algorithm is the basis for the selection of the forwarding nodes and involves repeated selection of one-hop neighbours covering no more than two-hop neighbours until complete coverage of all two-hop neighbours is achieved. In the packet, the identifiers (IDs) of the chosen nodes are piggy-backed as the forwarding list. The forwarding list is decided by a receiving node when it is required to forward the packet anew.

The approach put forth in the present study involves selection of the optimal nodes for forwarding RREQ messages from existing neighbours based on the application of the dominating set model. The information related to the forwarding list supports the broadcast of the RREQ messages. In this manner, irrelevant RREQ forwarding to the destination node is avoided and the overhead of RREQ of AODV is regulated.

A. DOMINATING SETS (DOMINATION IN GRAPH THEORY)

In the following part, the theory of domination in graphs is succinctly reviewed, since dominating set computation is so important to the proposed approach.

It is assumed that a set of wireless mobile nodes is denoted by an undirected graph G = (V, E), with V an E denoting a set of vertices and a set of edges, respectively. If all $n_i \in V$ belong to D or are proximal to a component of D, then a set $D \subseteq V$ of vertices in graph G is considered to be a dominating set (DS) [15]. Furthermore, the DS is considered to be connected (i.e. CDS), if the graph generated by the nodes in D has connectivity. The computation of the minimum cardinality of DS or CDS of any random graph is considered an NP-complete problem [15].

The neighbouring nodes that forward the packet are established by the source node in dominant pruning (DP). The distributed CDS algorithm enables selection of the forwarding nodes, with piggy-backing of the IDs of the chosen nodes in the packet forwarding list. The forwarding list is decided by a receiving node when it is required to forward the packet anew. When all forwarding nodes have been exhausted, flooding stops.

B. Dominant Pruning Algorithm

The process of selection consists of four steps.

In step 1, it is assumed that F(u,v) = [ ] (empty list), Z = Ø (empty set) and $K = U\ S_i$. For $v_i \in B(u,v)$, $S_i = N(v_i) \cap U(u,v)$.

In step 2, set S_i with maximum size in K is identified.

If two such sets are identified, then the chosen one is the one with the minimal identification.

In step 3, for every $S_j \in K$, $F(u,v) = F(u,v) \parallel v_k$, $Z = Z\ U\ S_i$, $K = K - S_i$ and $S_j = S_j - S_i$.

In step 4, if Z = U(u,v), then the process is terminated otherwise step 2 is repeated.

Two-hop neighbourhood information is retained by each node and the sharing of adjacent node list between neighbouring nodes enables its dissemination. A set cover based is established with the help of the distributed algorithm DP.

C. Route Request Algorithm Using DP Algorithm

RREQ and RREP messages are the basis for identification of routes on demand (e.g. AODV [3] and DSR [4]). Although different protocols involve different message management, message functionality does not change – the forwarding of a request continues until a node with a viable route to the destination or the actual destination is encountered, at which point a reply message is returned to the source node. Tuning is applied to a number of parameters, including duration of request caching, request timeout, and hello timeout, and the protocol may be helped to perform better depending on the choices made. The broadcast of RREQs takes the form of an unrestricted broadcast or and expanding ring search. In both cases, significant packet collision occurs in wireless networks with contention-based channel access due to the flooding process that ensues.

Broadcast RREQs do not occur throughout the network, but solely in the proximity of the destination and even then they are delayed as much as possible through unicasting to an area near the destination based on information about previous routes to a destination. This procedure is supplementary to the decrease of the number of nodes required for dissemination of broadcast-based transmission RREQs through the application of DP. The pseudo-code for the amended RREQ is provided by the RREQ algorithm. The steps of the process of RREQ management are outlined below:

- DP is employed by an RREQ source to determine its forwarding list if it lacks prior destination route information or if it is attempting to send the RREQ again. The packet is then broadcasted (Lines 8, 9, and 14).
- DP is also employed by the RREQ source to determine its forwarding list (Line 9) if it possesses information about a destination route recently become unavailable and a viable route to the subsequent hop to the destination exists (Lines 2, 3, and 4). However, the RREQ packet is unicasted rather than broadcasted by the node to the previous subsequent hop to the destination that is known (Line 12).

The information contained in the RREQ packet, namely, forwarding list, penultimate forwarding list and source node, enables a forwarder that cannot answer a received route request to determine its own forwarding list. The forwarder then updates the packet with the calculated forwarding list and either broadcasts or unicasts it, according to which of the two first cases are relevant.

RREQ Algorithm

```
Data : $n_i$, destination D, $B_i$, $U_i$
Result : Unicast the RREQ, or Broadcast the RREQ Begin

if recently expired route to D and not retryingthen
    NextHop←previous_nextHop(D)
    if validRoute(NextHop) then
        result←Unicast
    else
        result←Broadcast

else
    result←Broadcast
$F_i$←DP( $n_i$,$B_i$, $U_i$)
Update RREQ packet with $F_i$
if result== Unicast then
    Unicast the RREQ packet to NextHop

else

    broadcast the RREQ packet
end
```

The RREQ eventually arrives at a node with a destination route or the actual destination. The purpose of the strategy proposed in this study is to unicast a RREQ to an earlier location of the destination, in order to diminish the route discovery delay. There are two factors determining the efficiency of this strategy, namely, how new the prior known destination route is and the speed with which the destination node shifts from its earlier known location. RREQ broadcast is undertaken if all destination routes have been eliminated by an intermediate node, so that the RREQ broadcast to an area nearest to the destination is delayed. The RREQ is automatically broadcasted by the source node if the unicast method is unsuccessful or no prior destination route exists.

Forwarding lists may not include all neighbourhood nodes as modifications in topology could lead to erroneous two-hop neighbourhood information. In cases of broadcast requests, this is not a significant issue as the request may reach a node that has not been included in the forwarding list and can answer if it possesses a destination route.

D. Enhanced Dominant Pruning Algorithm

Total dominant pruning (TDP) and partial dominant pruning (PDP) are the two advanced dominant pruning algorithms that have been put forth by Lou and Wu [6].

The TDP algorithm is defined by the fact that the set of two-hop neighbours included in the forwarding list F of a node v is restricted to $U = N(N(v)) - N(N(u))$ if node v is the recipient of a packet piggy-backed with N(N(v)) from node u. Enhancing use of bandwidth through piggy-backing in the broadcast packet of two-hop neighbourhood information of every sender is the overall goal of the of this algorithm.

E. Partial Dominant Pruning Algorithm

The PDP algorithm is similar to the DP algorithm in that there is no piggy-backing of the sender’s neighbourhood information with the broadcast packet. Additional nodes from neighbours of every node in $N(u) \cap N(v)$ can be removed, besides removal of N (u) and N (v) from N (N (v)), which occurs in the DP algorithm. P (u,v) (or simply P) = $N(N(u) \cap N(v))$ represents this kind of set of nodes. As a subset of N(N(u)), P can be removed from N(N(v)) without difficulty, and therefore $U = N(N(v)) - N(u) - N(v) - P$ can be used to denote the two-hope neighbour set U in the PDP algorithm. Furthermore, when P = N(N(u)∩N(v)), U = N(N(v)) – N(u) – N(v)-P and B = N(v) – N(u), U can be demonstrated to be a subset of N(B).

F. Adaptive Partial Dominant Pruning Algorithm [19]

An algorithm comparable to PDP is adaptive dominant pruning algorithm (APDP), with the exception that, in the latter, neighbouring nodes of U are removed from U, in addition to the removal of N(u), N(v) and P from N(N(v)).

APDP Algorithm

1 Node v uses N(N(v)) ,N(u), and N(v) to obtain P = N (N(u) ∩ N(v)), U^1 = U – E where U =
N(N(v)) – N(u) – N(v) – P and E is the set of
equivalent and adjacent nodes in U and B =
N(v) – N(u)
Node v calls the selection process to determine
F.

The distinction among the PDP algorithm and the APDP algorithm can be highlighted with the scenario of a 12-node sample ad-hoc network (Figure 1). All nodes as well as one-hop and two-hop neighbour nodes are indicated in Table 1.

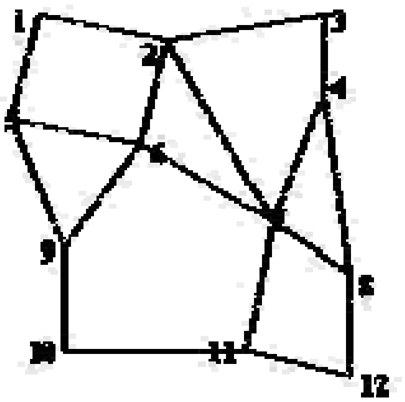


Figure 1: 12-node ad-hoc network

Table 1: PDP algorithm

u	v	P	U	B	F
Ø	6	Ø	1,3,4,8,10,11	2,5,7,9	7,2,9
6	7	1,3,6,7	10,12	4,8,11	11
6	2	2,4,6,8,11	Ø	1,3	[ ]
6	9	1,6,9	9	10	10
7	11	Ø	9	10,12	10
9	10	Ø	7,12	11	11

Table 2: APDP algorithm

U	V	P	U	B	F
Ø	6	Ø	1,4,8,11	2,5,7,9	7,2
6	7	1,3,6,7	10,12	4,8,11	11
6	2	2,4,6,8,11	Ø	1,3	[ ]
6	9	1,6,9	9	10	10
7	11	Ø	9	10,12	10
9	10	Ø	7,12	11	11

In keeping with the approximation minimum connected dominating set (AMCDS), the number of forward nodes is reduced to four through restriction of the minimum connected dominating set by the lower bound to {2, 6, ,7, 11}. By contrast to the PDP algorithm that comprises six forwarding nodes, the approach suggested in this study requires only five nodes, including the source node, {2, 6, 7, 10, 11}.

Table 3: The two-hop neighbours of every node

V	N(v)	N(N(v))
1	1,2,5	1,2,3,5,6,7,9
2	1,2,3,6,7	1,2,3,4,5,6,7,8,9,11
3	2,3,4	1,2,3,4,6,7,8
4	3,4,7,8	2,3,4,6,7,8,11,12
5	1,5,6,9	1,2,5,6,7,9,10
6	2,5,6,7,9	1,2,3,4,5,6,7,8,9,10,11
7	2,4,6,7,8,11	1,2,3,4,5,6,7,8,9,10,11,12
8	4,7,8,12	2,3,4,6,7,8,11,12
9	5,6,9,10	1,2,5,6,7,9,10,11
10	9,10,11	5,6,7,9,10,11,12
11	7,10,11,12	2,4,6,7,8,9,10,11,12
12	8,11,12	4,7,8,10,11,12

In the case of the PDP algorithm, the forwarding list of node 6 remains unchanged - F (Ø,6) = [7,2,9], while the forwarding list for node 7 is F(6,7) = {11}. Likewise, U(6,2) = N(N(2)) – N(6) –N(2) –P(2,6) = Ø and F(6,2) = {10} can be derived from P(6, 2) = {2, 4, 6, 8, 11}. Hence, there are six forward nodes overall (1+3+2). Table 2 provides further information regarding P, U, B and F.

The PDP algorithm gives a total of six forwarding nodes in the cited example, including the source node ({6, 2, 7, 9, 11, 10}). In the suggested approach based on an improved PDP version (i.e. APDP), the existing U is defined more broadly to determine presence of any neighbouring nodes and to eliminate them. Table 3 outlines the findings of the suggested approach.

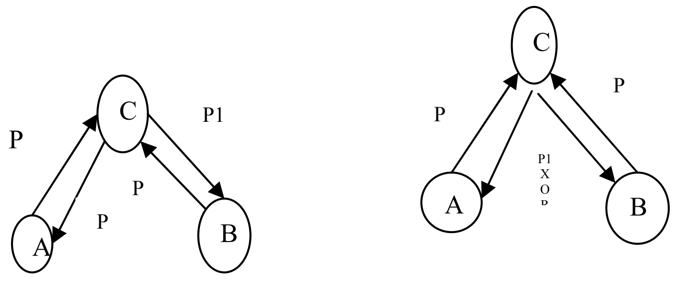
III. NETWORK CODING MODEL FOR EFFICIENT ROUTING

The purpose of network coding is to endow the nodes with “intelligence” and capacity for computation, allowing them to apply coding procedures on the content itself. Hence, network coding is conducive to the creation of progressive frameworks for communication systems and transmission models that could support the requirements of good network capacity and improved performance of the Future Media Internet. The creation of new packets through the merging of packets obtained on their incoming margins can be achieved by intermediate network nodes through the novel paradigm of network coding. In fact, given that network coding ensures a compromise between communication capacity and costs of computation, the technologies that could be developed based on this paradigm could enable the creation of better and more effective future networks. Furthermore, network efficiency can be significantly enhanced via network coding. In the case of standard routing, the data packets are not modified at intermediate nodes and the packet contains information intended to improve network performance, in addition to the actual message. On the other hand, in network coding, data packets undergo modifications at intermediate nodes through techniques such as xor or linear coding. The next sections comprehensively address network coding applications, benefits, related research and limitations, while a discussion on routing protocols aware of network coding is extended as well.

The mechanism underpinning network coding seeks to reduce the number of transmissions through the merging of multiple packets at intermediate nodes into just one packet that the receiving nodes can decode. This is made possible by coding techniques such as linear coding or xor coding. Moreover, packets overheard from adjacent nodes are employed in the decoding rather than being removed, which is another aspect in which network coding differs from standard routing. Furthermore, owing to their ability to overhear over network transmissions the nodes use the exchanged information to undertake decoding without additional overhead. Due to these characteristics, network coding is clearly compatible with the broadcasting nature of wireless network routing.

Both the intermediate and receiving nodes must have access to knowledge regarding packet information. The intermediate node sends the packet information to its neighbours, thus further complicating the process. Wireless networks have limited energy and bandwidth, which is why achievement of improved capacity and lifespan is so important. This achievement can be facilitated by network coding as it increases network capacity and reduces the number of transmissions.

The mechanism of network coding is illustrated in Figure 2, based on the example of nodes X and Y, which use the intermediate node R to respectively transmit packets P1 and P2 to one another. For this purpose, standard routing would require four transmissions, as transmission of P1 and P2 by R occurs separately. However, in network coding, the two packets are transmitted together (P1+P2) by R since it can apply the xor coding technique. X and Y receive the combined packet and can then each undertake the decoding of P2 and P1, respectively. The opportunities for coding depend on the route paths that have been established. One study successfully managed to reduce the number of transmissions according to approaches for the selection of forwarding nodes by employing network coding to achieve broadcasting [26].



(a) Without Network Coding (b) With Network Coding

Figure 2: Schematic representation of network coding

The significance of the current study resides in the fact that aims to apply network coding in conjunction with dominant sets in order to reduce the number of transmissions and thus improve the efficiency of energy usage in MANETs. Additionally, to determine a heuristic solution for optimal network coding, the study also involves subjection of forward node sets to ant colony optimisation.

The study uses network coding for energy-efficient routing in multi-hop wireless networks, with the purpose of homogenising the energy capacity of the network nodes and thus expanding network lifespan. Broadcasting represents the foremost process of routing protocols. To aid path selection, the broadcasting mode whereby information is transmitted by a source node to all nodes in the network is employed in this study. Additionally, a key goal of the study is to diminish the number of transmissions to make broadcasting more energy-efficient.

In the case of a point-to-point communication network, such as the Internet Backbone, with a directed graph G = (V, E), where V and E respectively represent sets of nodes and edges with noiseless information sharing between nodes, network coding is essential to optimise the network, since the assumption that multicast information is a “fluid” amenable to routing or replication at intermediate nodes is insufficient. Furthermore, it is necessary to decrease the amount of energy employed by each packet transmission between source and destination, according to the goal of network flow maximisation. This requires finding out the overall amount of energy consumed by packet transmission between route nodes to the subsequent hop. The energy consumed by a single packet can be determined with the equation below:

The condition and situation of neighbouring nodes are known to all nodes and they can also detect coding opportunities and even conduct coding, if the receiving nodes have decoding abilities. Network coding is directly dependent on the broadcast nature of the wireless environment when it comes to the sending of one encoded packet to multiple receivers. To this end, the wireless network has to be transformed into a graph with the edge between two nodes denoting the radio range that enables those nodes to communicate. The nodes retain the overheard packets only for a short while. Furthermore, the nodes let adjacent nodes know about the heard packets by annotating the packets they send. The nodes can apply the xor coding technique to multiple packets to send them as a single combined packet, as long as the targeted next hop has enough information to decode an encoded packet. However, the nodes must avoid excessive overhead when acquiring information about packets overheard by adjacent nodes, to make sure that coding is applied to the right set of combined packets. Moreover, a coded packet is meant for at least two next hops and therefore the nodes must ensure that their information can reach every next hop. Coding opportunities for forwarding multiple packets in a single transmission can be detected and taken advantage of through this process.

listening, coding and learning are the main components of network coding, on the basis that the forwarding node is aware of the next hop of each packet waiting to be transmitted.

A. Listening

In network coding, the nodes must undertake listening to and storage of the packets that could be subsequently used for the decoding of coded packets. There are two major sources from which these packets can be obtained:

1. Packets that the nodes themselves transmit: Referring to the example previously presented in Figure 3.1, the X and Y nodes store copies of the packets sent to the router so that the coded packet returned by the router can be decoded.
2. Packets that the nodes overhear: Due to the fact that wireless environments possess a broadcast character, packets can be easily overheard by the nodes, provided that they have omnidirectional antennae. Packets are usually propagated to a single next hop and the nodes ignore the overhead packets that are not meant for them. On the other hand, all messages transmitted over the wireless network are scanned by nodes in network coding and the overhead packets are kept for a duration T with a value higher than the maximum one-network latency (T generally has a value of 0.5 s).

B. Learning

The packets that the neighbours of a node retain in their listening module are monitored by the learning module because they are important for coding decisions. Since deterministic information can underpin this process of supervision, reception reports sent by the neighbouring nodes or acknowledgement of the nodes as prior hops on the packet transmission route is necessary to validate that packets are available.

Nodes cannot perform network coding if they are unaware of the packets present in the packet pools of neighbouring nodes. They can obtain this knowledge from reception reports, which are disseminated via annotation of broadcasted information packets and are the means through which nodes can let their neighbours know about the packets they possess. For nodes lacking information packets for standard broadcast, transmission of reception reports is done in special control packets.

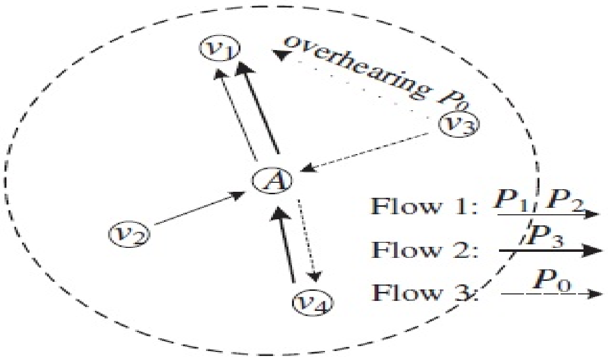
C. coding and decoding

By enabling combined coding of packets by nodes, network coding contributes to improve throughput. All nodes retain the packets to be broadcasted to the next hop in their FIFO forwarding queue. Awareness of packet transmission opportunities prompts the nodes to determine whether other packets in the queue can be used for the coding of the first packet in the queue. To attain the highest throughput, the number of native packets coded in a single transmission has to be elevated by the nodes and at the same time all targeted next hops must be ascertained to have enough information to decode the received packets. Neighbouring nodes that overhear these packets retain them in their packet pools. The following figures present the basic procedures of the xor process on packet data bits.

If all next hops r_i have every n-1 packet $p_j$for j≠i, then a node can apply the xor coding technique on n packets (p_1, p_2,..,p_n) combined in order to transmit these packets to n next hops (r_1, r_2,….,r_n).

In Figure 3, a large-sized packet is possessed by each of Flows 1, 2, and 3, which are directed towards neighbours v1 (Flows 1 and 2) and v4 (Flow 3) through node A. It is assumed that there is just one case of packet overhearing, namely, packet P0 transmitted by v4 to node A is overheard by v1.

Flow is the core element of the network coding model proposed in this study, with a queuing structure based on flow and a novel coding algorithm that is aimed to facilitate automatic decoding. If it does not have enough packets, a targeted receiver will be unable to derive a new native packet from the received coding packet, and therefore it will discard it. Furthermore, the suggested flow-based configuration can be used even in cases where automatic decoding is impossible, but extended decoding deferral is the cost of obtained improvement.



(a) Flows passing through node A.

Figure 3: Network flows

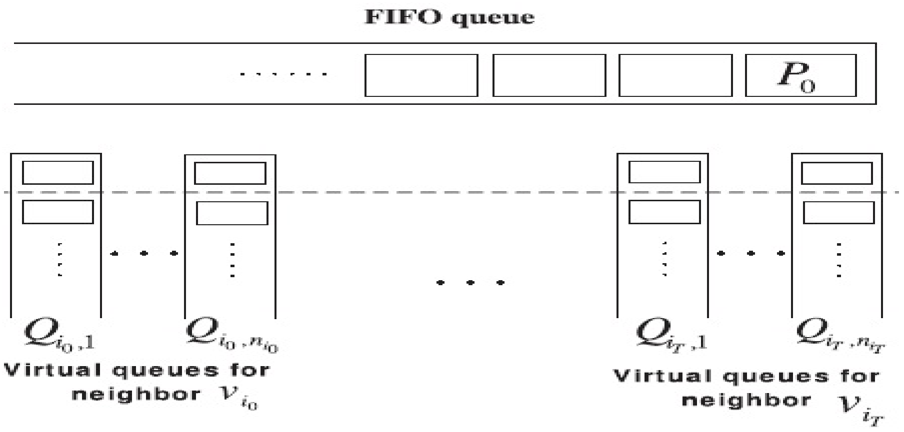


Figure 4: Network node queues

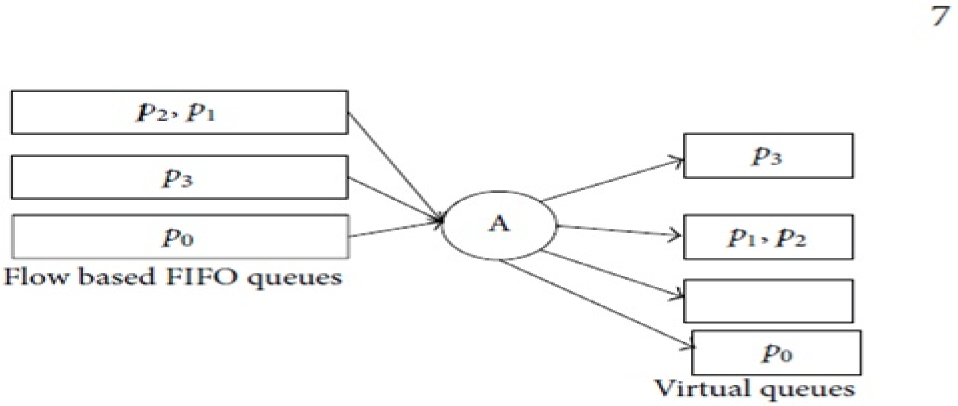


Figure 5: Flow-based queuing structure

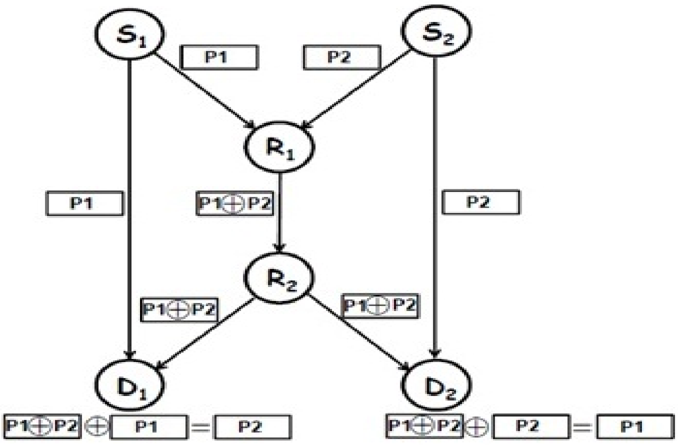


Figure 6: Schematic representation of the butterfly network associated with network coding

Comparable to the current coding scheme and in keeping with packet rearrangement, only the first packets in the virtual queues are compatible with P0 coding. Therefore, the novel queue structure does not necessitate packet rearrangement. Moreover, the virtual queue structure ensures that more possible packets are available for coding, since P0 coding could potentially be performed by the oldest packet of each flow. Actually, the maximum number of possible packets is made possible by the queue structure, owing to the condition that packet rearrangement is not allowed.

Figure 5 illustrates an example in which P3 is the first packet of the virtual queue in the flow-based queuing structure. Thus, the coding algorithm could provide P0+P3 as a potential coding solution. Consequently, a greater number of coding opportunities could be generated by this queue structure if the number of possible packets is elevated.

Figure 7 shows the ideal coding situation that could not only be advantageous to as many neighbours as possible, but could also reduce the number of transmissions. In this illustrated situation, node B transmits coded packets to its neighbours and the packets possessed by A, C and D are highlighted. If packets p1 and p4 are sent by B to A and D, respectively, while both packets p2 and p3 are sent by B to C, and if p1 and p2 are combined at B through application of the xor technique and broadcast, then solely C will be able to receive and decode p2. Similarly, only A and C will be able to receive and decode p1 and p3, respectively, if these two packets are combined at B. Furthermore, the number of transmissions can be reduced if p1, p3 and p4 are combined at B and then sent to be decoded to nodes A, C and D, respectively. Consequently, the form in which p1 will be received by A is p1=p4+p3+p1+p3+p4.

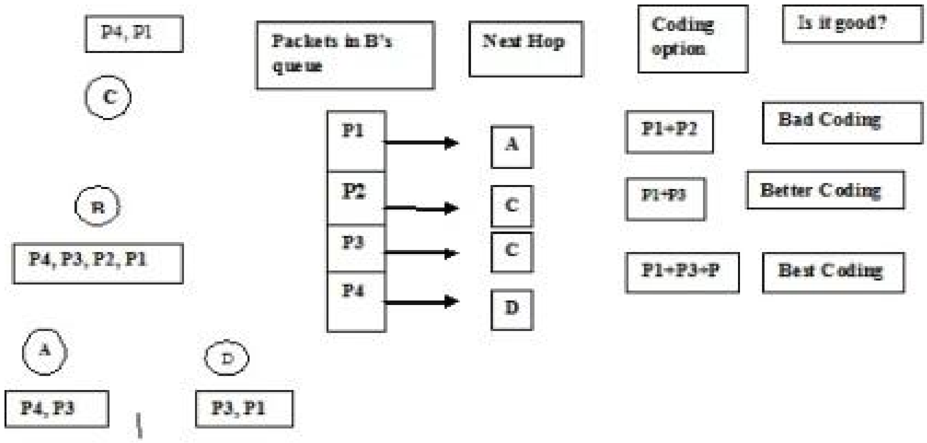


Figure 7: Ideal coding settings for network coding

The coding/decoding module is in charge of identifying opportunities for the combined coding of several packets and their broadcast in a single transmission. The module additionally decodes coded packets at receiving nodes, maintains a FIFO output queue for the addition of decoded as well as non-decoded received packets, and selects packets from the output queue to be coded and transmitted together when the MAC layer alerts to an existing transmission opportunity. Additionally, the coding module must take into account the fact that combined coding of n packets requires a node to ensure that the remaining n-1 packets are available at every one of the n next hops, besides the packet meant for it.

Packet decoding is a straightforward process. All the IDs of the native packets contained in the encoded packet are verified by the receiving node. The set consists of n-1 packets, besides the packet meant for the node. To obtain the native packet intended for that node, the xor coding technique is applied alongside the received encoded packet to the n-1 packets, once they are derived from the listening module. If the listening module does not contain the n-1 packets, the coded packet is eliminated. Such an action is usually taken, despite the possibility of optimization by decoding a packet that is impossible to decode at a later time when the necessary information is available.

IV. SIMULATION RESULTS

The simulation conducted in this study was undertaken with the network simulator 2.[8] and the simulation parameters are listed in Table 3. The simulator clock indicated that the simulation lasted for a quarter of an hour. Two fields measuring 500 X 500 m^2 and 2000 X 2000 m^2, respectively, were used with a random distribution of 45 nodes, each with a power range of 250 m. The DP algorithm was applied to carry out the simulation for AODV.The simulation was repeated four times with a node pause time varying in the range 15-30 s and a step interval of 5 s. The following results part provides the graphs.

Several metrics are employed to assess how the suggested protocol performs.

Packet delivery ratio (throughput): The ratio of the number of packets issued by the application layer CBR sources to the number of packets reaching the CBR sinks at the end destinations is known as the packet delivery ratio. Compared to standard AODV, AODV with dominating sets is associated with a higher packet delivery ratio (Figures 3 and 7).

Number of control packets: By contrast to standard AODV, AODV with dominating sets has a lower number of control packets from different nodes (Figures 4 and 8).

Number of route requests: The number of control packets produced by the totality of the nodes in the simulation is known as the number of route requests, which is higher in standard AODV than in AODV with dominating sets (Figures 2 and 6).

End-to-end delay: Unlike standard AODV, AODV with dominating sets has a better end-to-end delay (Figures 5 and 9).

Table 3: Simulation Parameters

Parameter	Value	Description
Number of nodes	160 and 40	Simulation Nodes
Field range x	500m and 2000	X-Dimension
Field range y	500m and 2000	Y-Dimension
Power range	250m	Nodes power range
Mac protocol	IEEE 802.11	MAC layer protocol
Network Protocol	&Ro AODV ugh AODV	Network Layer
L Transportayer Protocol	UDP	Transport Layer
Propagation Function	FREE-Space	Propagation Function
Node placement	Random	Nodes re distributed n random manner
Simulation time	15M	According o simulation clock
Mobility Interval	10-30sec	Pause time of node

Performance of AODV with dominating sets and AODV in the Terrain Dimensions (500, 500)

Throughput can be enhanced, while both end-to-end delay and the number of route requests can be diminished if network coding is applied to AODV with dominating sets.

Comparative assessment of throughput in AODV and AODV with NC based on dominating sets

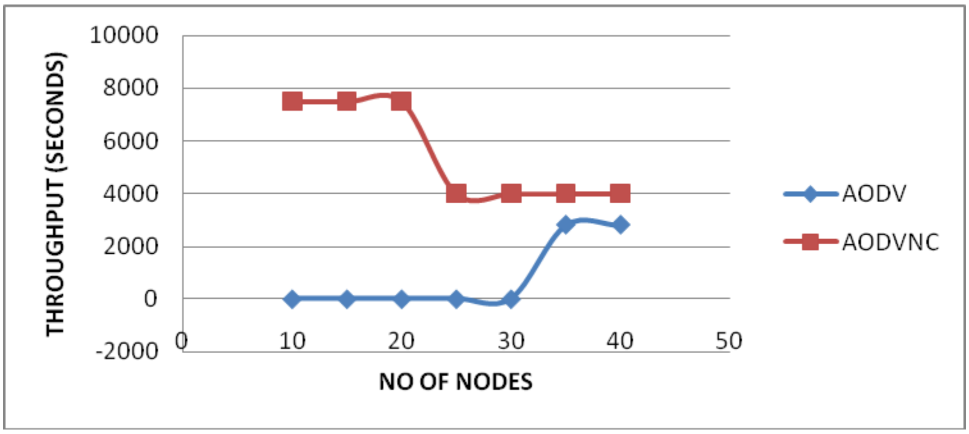


Figure 8: Comparison of throughput

Comparative assessment of end-to-end delay in AODV and AODV with NC based on dominating sets

End to end delay is reduced if network coding is applied in AODV routing protocol.

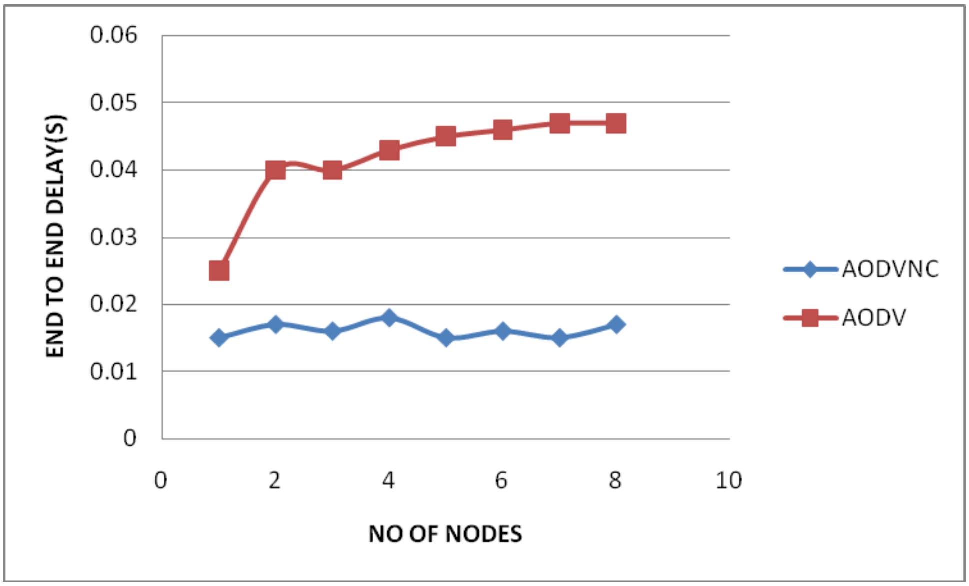


Figure 9: End-to-end delay measured in seconds

Comparative assessment of route request in AODV and AODV with NC based on dominating sets

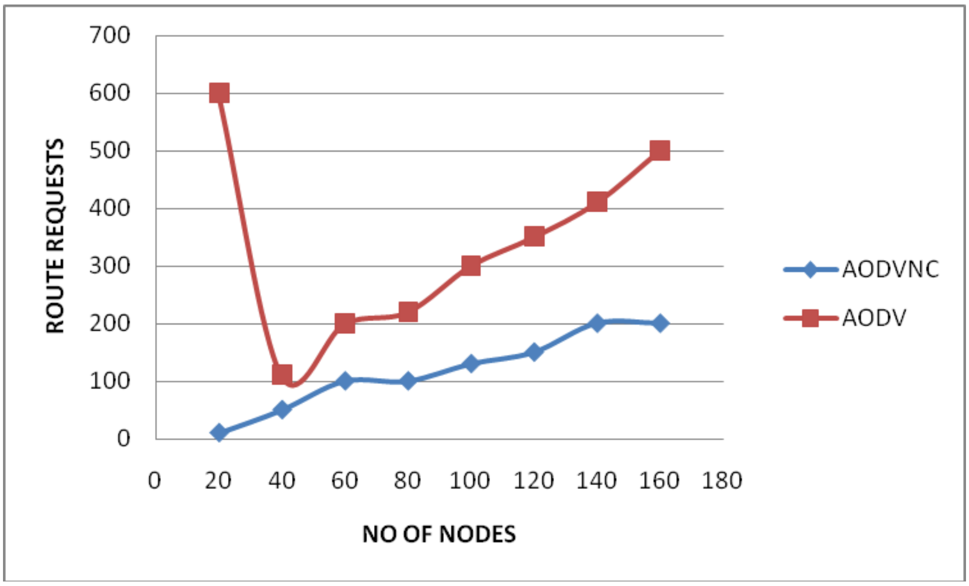


Figure 10: Comparative examination of route request

V. CONCLUSION AND FUTURE WORK

An advanced strategy of dominant pruning different from standard dominant pruning heuristic in that it enables the reduction of irrelevant network transmissions has been proposed in this study. Irrelevant transmissions defer the response of RREQs in the process of route discovery by increasing the number of packet collisions. By contrast to conventional DP, it has been demonstrated that DP could diminish the number of broadcast transmissions. In this study, a neighbour protocol was created as part of the AODV, since a two-hop neighbourhood is necessary for DP to establish the forwarding list. This enables the local topology to be more precisely rendered, and implicitly, the forwarding list can be determined with greater accuracy. In addition, an APDP algorithm as an advanced form of PDP has been put forth. The DP algorithm was applied to compare how AODV performed compared to AODV with NC. Further research would be useful to apply the PDP algorithm to compare the performance of AODV to the performance of AODV with NC.

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