Protocol for Improved Network Coding Opportunity Discovery for Inter-connected WBAN Multihop Relay Medical Networks

Zilole Simate*, Chika Sugimoto*, Ryuji Kohno*†

* Graduate Studies Department, Physics, Electrical and Computer Engineering Yokohama National University, Japan
† Centre for Wireless Communications, Faculty of ITEE, University of Oulu, Finland
*simate-zilole-kh@ynu.jp, chikas@ynu.ac.jp, kohno@ynu.ac.jp, †ryuji.kohno@ee.oulu.fi

***Abstract*—By modifying existing routing schemes, network coding opportunities using location information for use in interconnected WBAN Multihop Relay Medical Networks is achieved. Current techniques use the time to live parameter. By using routing discovery schemes combined with location information, potential coding nodes are recognized. However the gateway nodes in multihop relay environment experiences high traffic intensity. When Wireless Body area Networks interconnect with the Multihop networks, they can experience a degraded quality of service due to congestion in the multihop relay nodes. To address this problem this paper analyses using network coding techniques and network coding opportunity discovery to find potential coding neighbours as a protocol.**

Keywords-WBAN; Multihop networks; Adhoc Networks.

I. INTRODUCTION

One of the challenges faced in practical network coding application is discovering of network coding opportunities for intermediate nodes to perform network Coding. The number of coding opportunity has an impact on the performance of the network in terms of packet latency because of the complexity introduced by network coding at each intermediate node in the multihop relay network. From the seminal paper [1], the concept of network coding was introduced. Routing protocols in networks gather a lot of information which can be a basis for a network coding protocol, in Ad hoc On-Demand Distance Vector Routing (AODV) is used extensively and described in great detail in [2].The Authors in [3] study on converting an on demand protocol into proactive multihop routing protocol for link failure prediction. In [4], they propose a new enhanced AODV routing protocol, which is based on the most stable route between the source and destination. To consider security concerns,[5] looks at a trusted AODV routing protocol. In [6], work is carried on reliability of AODV.

A. *Current Network Coding Node Discovery*

Coding opportunities need to be discovered to improve throughput, also the number has to be minimized to reduce latency. The current method used in detection of coding opportunities [7] works as follows: Node I transmits a packet which is received by both node K and node J if they are within Node I's transmission range as illustrated in fig 1.The received packet by node J is retransmitted with a reduction in the Time to Live (TTL) from N to N-1 shown in fig 2.

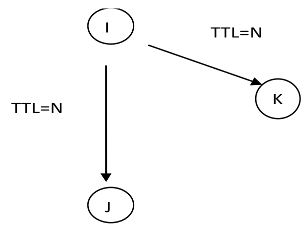

Figure 1 Node I broadcasts packet with TTL=N

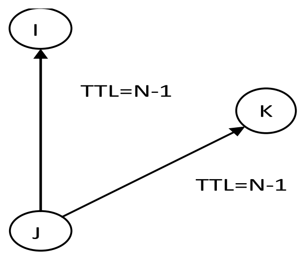

Figure 2 Node J re-broadcasts packet

The retransmitted packet received by node K is compared to the original packet. If the retransmitted packet received at node K has a lower TTL value by one, then node K determines that nodes I and J are potential neighbours. Packets from I and J with the same destination can then be network coded thereby increasing throughput. The role of node K in the network is to act as a coding point, therefore it has to identify coding opportunities in the network.

B. *Proposed protocol for discovering potential coding nodes*

Node K hears many transmissions from other nodes and therefore has to decide what pairing to do. By modifying the AODV packet structure to carry location information, during routing discovery node location is also obtained. A new packet Mobility request (MREQ) is introduced as a control packet for purpose of the gateway node to send to a command any neigbouring node so as to create opportunities for network coding. Location information is introduced in a Route Request packet (RREQ) in the existing AODV routing scheme.

C. Packet Structures

If the direction of arrival of the packets is within a pairing threshold angle ψ, then the coding node can suggest a pairing of the nodes. This suggestion is in form of a control packet sent either to Node I or Node K based on criteria which can be determined. This control packet suggests the movement of the non neighbour node in order to be in the communication range of the other node thus forming a neighboring pair. The node receiving the command to change location has to perform its own cost benefit analysis.

The steps are as follows:

i. Node K obtains/Calculates location of node I and node J.
ii. Node K evaluates if node I and J are potential coding Neighbours.
iii. Node K obtains transmission range of node I.
iv. Based on decision criteria, node K sends MREQ for node I or J to move.
v. Node K determines the how urgent the node has to move based on delay constrain.
vi. Based on the urgency, node I or J determine the speed and moves into the other nodes range.
vii. Node K confirms that node I and node J are now a coding pair and can now perform network coding on packets from node I and node J going to a particular destination.

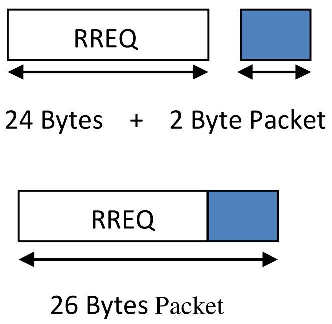

Figure 3. RREQ with added 2 byte

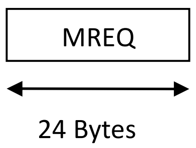

Figure 4. MREQ packet

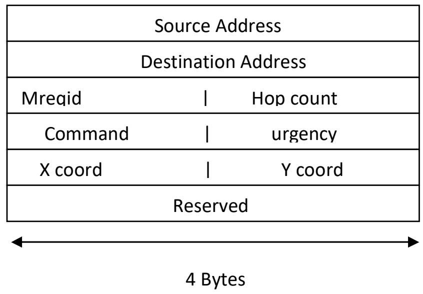

Figure 5 .Detailed packet structure for MREQ

II. DISCOVERING CODING OPPORTUNITIES

Packet has an option to carry position information. The Node can also perform ranging, if it has ranging capabilities like those of Ultra Wide Band (UWB) to obtain the distance to the neighbouring node. Figure 6 show three nodes, in this diagram the centre node can communicate with the other two nodes while the other two nodes cannot. Using AODV, location information of nodes can be done during route discovery. The centre node interconnects with various other WBAN gateways and provides access to the multi-hop or mesh network for transmission of medical data. There are four quadrants numbered one to four as well as border lines between the quadrants which are four. The gateway node can as a result keep the neighboring node's ID mapped to its quadrant and angle.neigbours falling in the same quadrant can as a result be grouped together.

Once the gateway node identifies a potential coding pair, it sends a command using MREQ to move towards the other node. Because the gateway node is connected to many WBAN nodes, the traffic intensity can be high.We examine the impact of RREQ and data from one WBAN gateway to the mesh gateway node.

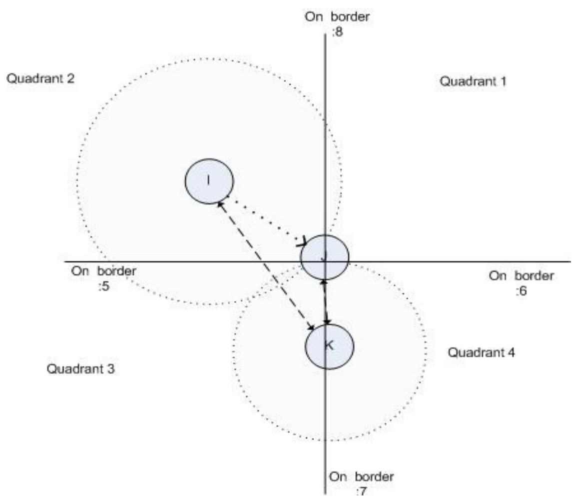

Figure 6. The mesh node classifies its neighbours into quadrants and makes a decision to pair nodes for network coding.

A. *Traffic intensity on Mesh gateway*

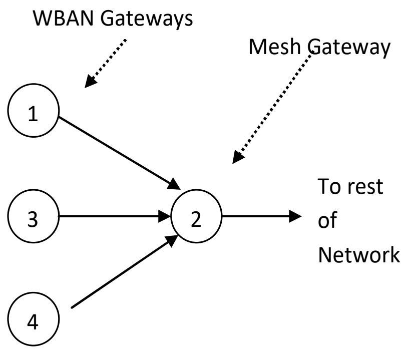

Figure 7. Evaluation Model

Given N WBAN connections, the total arrival rate λ, on the mesh gateway is given by:

$$\lambda = \sum_{i=0}^{N} \lambda_i \qquad (1)$$

From queuing theory the probability of blocking for a M/M/1/B queue is given as

$$P_B = \left(\frac{(1-\rho)\rho^n}{1-\rho^{B+1}} \right) \qquad (2)$$

Where P_B is the blocking probability, the probability that the Buffer in the Mesh gateway is full, n is the number of packets, ρ is the utilization factor and B is the size of the buffer or queue. Packets which arrive when the buffer is full are dropped. Given two packets from the same node, in the event that a route is not found, the next RREQ is sent .The interval between two subsequent RREQ packets is when the Wait for RREQ timer expires. Therefore if a path has not been discovered, another RREQ is sent until a path is found or the maximum number of retries is reached. A route request is sent every wait for route reply (RREP) expiry and at every path discovery expiry period. There are several reasons why the timeout may expire before the path is discovered. In this paper we look at the cause being congestion at the mesh gateway. Congestion occurs when the buffer at the gateway node is full; therefore every packet which arrives is dropped, including the AODV route request control packet control packet, RREQ.

Traffic intensity, T_1:

$$T_1 = \frac{\sum_{i=1}^{N} \Upsilon_i}{\sum_{j=1}^{N} \xi_j} \qquad (3)$$

Where:

Υ_i = size for each RREQ packet i
ξ_j= wait for RREP timer

We assume all RREQ are generated successfully
We assume the wait for RREP interval is exponentially distributed with parameter t.
It can be observed in (3) above that for the case where there is no established path to the sink, the equation becomes deterministic. We take that all the AODV packets to be of the same size, therefore the traffic intensity T_1 becomes:

$$T_1 = \frac{\Upsilon N}{\xi N} = \frac{\Upsilon}{\xi} \qquad (4)$$

When a path is discovered successfully after reception of a RREP, the next RREQ packet has to wait a total of Path discovery time + packet transmission time.
Thus traffic intensity T_2 becomes:

$$T_2 = \frac{\sum_{i=1}^{k} \Upsilon_i}{\sum_{j=1}^{K} \varsigma_j + \sum_{s=1}^{K} \frac{X_s}{R_s}} \qquad (5)$$

Where:

Υ_i is size for each RREQ packet i.
ς_j is the path discovery time.
X_s is Data packet Size for packet s in the WBAN.
R_s is the transmission rate for packets.

Total traffic intensity,T_3 experienced by the gateway from a WBAN gate way is expressed as:

Considering the data packets:

$$T_3 = \frac{\sum_{s=1}^{N} X_s}{\sum_{s=1}^{N} \frac{X_s}{R_s}} \qquad (6)$$

Where:

X_s is Data packet Size for packet s in the WBAN
R_s is the transmission rate for packet s

B. *Network Coding protocol considering different Qos Levels in WBAN*

WBAN standard IEEE802.15.6 defines 0-7 QoS levels of packets. We propose a network coding solution accounting for the different Qos levels. The main idea is as follows: Each neighbouring coding node has an extra amount of reserved buffer. Given a multihop route, a node will receive indication by a control packet that traffic of a particular QoS level is about to be received. This signaling information indicates the traffic type about to be received, the time of arrival of the traffic and the required transmission time.

The number of buffered packets to be cleared from the mesh gateway depends on the Qos level of the incoming packets. For example, the Qos levels for Real time traffic and emergency data have strict stringent on delay. A buffer clearing factor for each class given by ρ_{i} for $i = (0, 1, 2, \ldots.7)$ is defined. Clearing factor ranges from 0-1 or in terms of percentage from 0-100%. For example highest priority ECG may take a value of 100% or a factor of one signifying that all packets in the buffer must be cleared. The packets in the buffer can be expressed as:

$$X=\{x1, x2, x3, x4\ldots\ldots.x_B\}$$

Where B is the Buffer size. The amount of cleared packets each class of packet a node N_{cp} is given by:

$$B\ \rho_{i=}N_{cp} \quad (7)$$

Where ρ_i is the clearing factor. For emergency packets when the buffer is full, all the contents of the buffers should clear.

$$B\rho_i \ - \ N_{cp}= 0 \quad (8)$$

The cleared packets are transferred to the neigbouring coding nodes. The size of coded packet transferred to neighbouring nodes is given by the sum of size of coded packets, coding coefficient size and class bits. The packet structure can be defined as follows:

F(X)	A	C

Figure 8. Packet structure from WBAN gateway to neigbouring nodes.

Where F(X) is the coding function matrix, A is the coding coefficient matrix and C is the class matrix. The transmitted coding matrix has each row representing time of transmission.

$$T1: [f(x_1, x_2, x_3, x_4)][a_{11}a_{12}a_{13}a_{14}][111]$$

$$T2: [f(x_1, x_2, x_3, x_4)][a_{21}a_{22}a_{23}a_{24}][111]$$

$$T3: [f(x_1, x_2, x_3, x_4)][a_{31}a_{32}a_{33}a_{34}][111]$$

$$T4: [f(x_1, x_2, x_3, x_4)][a_{41}a_{42}a_{43}a_{44}][111]$$

F(X) A C

Where T1, T2, T3, T4 is the time at which the coded packet is sent. Clearing rate from the WBAN gateway

$$Thr = \frac{\rho_i N_B}{T_c + \frac{\rho_i N_B}{\mu_c}} \quad (9)$$

Where Thr is the throughput. This simplifies to:

$$Thr = \frac{1}{\frac{T_c}{\rho_i N_B} + \frac{1}{\mu_c}} \quad (10)$$

Let the time to of a packet class be given by ΔT.By the time the packet arrived, the number of cleared coded packets would be:

$$Thr\ x\Delta T=Ncp \quad (11)$$

Therefore for the different Qos level of traffic in WBAN, the network problem becomes finding a code such that (7) is satisfied. The coding function is such that it increases the clearing rate of the buffered packets depending on the Qos level of the incoming packet selected by the clearing factor, ρi.

III. RESULTS AND DISCUSSION

When network coding is introduced, the coding function greatly contributes to the throughput and consequently the latency of the packets at the node. Five different service rates are compared, and the time to perform network coding on all packets is assumed to be exponentially distributed. We evaluated the scheme with service rates for the coded packets at 125KB/s, 75KB/s, 25KB/s,12.5KB/s and 1.25KB/s.As the service rate is increased, to higher levels, as the number of packets increase the throughput also increases linearly. In this evaluation 125KB/s or 1Mbps is the capacity limited by the type of network interface being used. The results from the figure 9 indicate that with the low service rate, as the number of packets increases, the throughput needed tends towards being a constant value. Figure 10 shows the traffic intensity on the mesh gateway due to the route request, RREQ when the wait timer for RREP elapses. The timers in the evaluation have been assumed to have an exponential distribution. Figure 11 shows the traffic intensity by the RREQ with an interval of the path discovery timed. Figure 12 shows that when data packets are considered, as well, the intensity quickly rises depending on the traffic type. This has implications on the buffer and energy of nodes. Introducing of a new packet structure and attaching additional fields for data seem to have no such effect on the gateway.

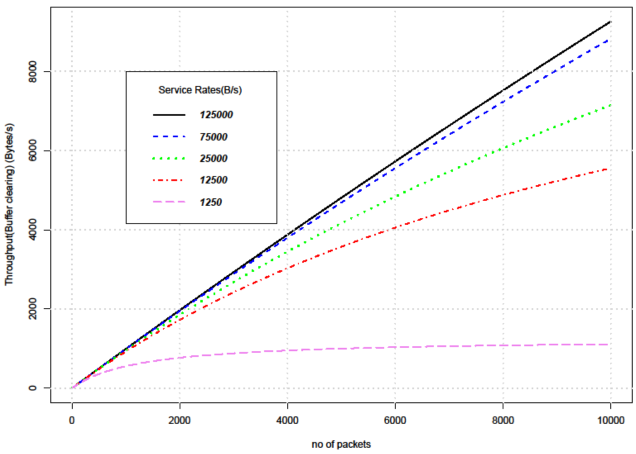

Figure 9. Throughput with clearance factor set to 100%.

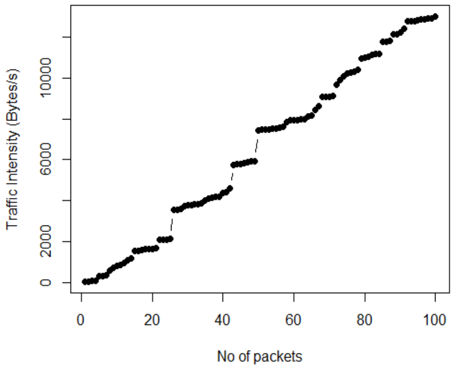

Figure 10. Traffic Intensity when the RREP is not received on time

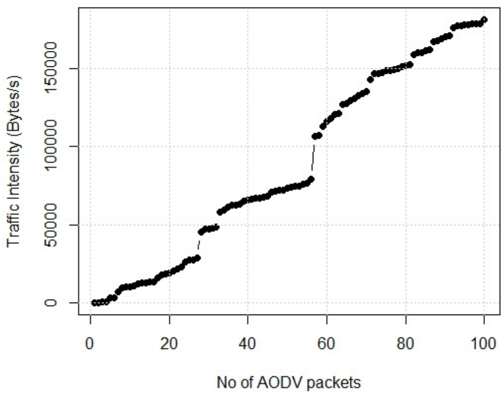

Figure 11. Traffic Intensity due to RREQ after successful route discovery

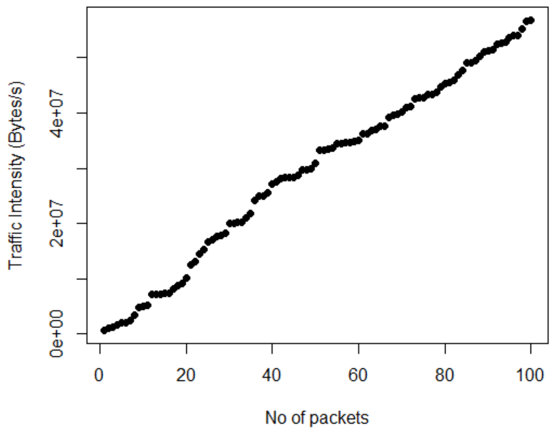

Figure 12. Combined traffic Intensity due to RREQ aft and transmitted data.

A. Drawback of proposal

The drawback of this proposal is the complexity that is introduced is introduced in obtaining location information. The coding node can obtain location information based on Array antenna techniques or by source nodes embedding location information in the packets they send. Both methods need to be evaluated for delay and throughput performance, and power requirements depending on the signaling load. This complexity can be the difference in implementation in networks within constrained environments such as internet of things (iot) devices and WBAN devices.

IV. Conclusion and Future Works

We analyzed the traffic intensity mesh gateway nodes experience when existing routing schemes are for network coding opportunity discovery. Depending on the QoS level of the incoming packets, and the number of nodes buffered or queued in the gateway nodes, the neigbouring nodes can be used to reduce latency by clearing the gateways nodes packets. The use of location information and how the occasion of each node is determined has an impact on the complexity of implementation especially in resource constrained environment. The discovered coding nodes can be used in guarantee meet delay.Future works has to consider the scaling of the network as more nodes increase.

References

[1] R. Ahlswede, Ning Cai, S.-Y.R. Li, and R.W. Yeung. Network information flow. Information Theory, IEEE Transactions on, 46(4):1204 –1216, July 2000.

[2] C. Perkins, E. Belding-Royer, S. Das, “Ad hoc On-Demand Distance Vector (AODV) Routing”,RFC3561, IETF MANET Working Group, July 2003

[3] Vishwayogita A. Savalkar, "Link prediction for identifying link failure using cross layer approach", Inventive Systems and Control (ICISC) 2018 2nd International Conference on, pp. 1120-1129, 2018.

[4] Shahin Tajik, Ghazal Farrokhi and Sadan Zokaei, "Performance of modified AODV (waiting AODV) protocol in mobile ad-hoc networks," 2010 Second International Conference on Ubiquitous and Future Networks (ICUFN), Jeju, 2010, pp. 160-164.

[5] S. Singh, A. Mishra and U. Singh, "Detecting and avoiding of collaborative black hole attack on MANET using trusted AODV routing algorithm," 2016 Symposium on Colossal Data Analysis and Networking (CDAN), Indore, 2016, pp. 1-6.

[6] R. Kumar, K. V. Arya, S. Shekhar and R. Agrawal, "An on demand routing protocol AODV with end to end reliability and backward route information," 2014 9th International Conference on Industrial and Information Systems (ICIIS), Gwalior, 2014, pp. 1-6.

[7] A. Neumann, C. Aichele, M. Lindner, and S. Wunderlich, B.A.T.M.A.N.,Internet-Draft, pages 1-24, 2008.