

# Opportunistic Routing with Secure Coded Wireless Multicast Using MAS Approach

E. Golden Julie, S. Tamil Selvi, Y. Harold Robinson

**Abstract**—Many Wireless Sensor Network (WSN) applications necessitate secure multicast services for the purpose of broadcasting delay sensitive data like video files and live telecast at fixed time-slot. This work provides a novel method to deal with end-to-end delay and drop rate of packets. Opportunistic Routing chooses a link based on the maximum probability of packet delivery ratio. Null Key Generation helps in authenticating packets to the receiver. Markov Decision Process based Adaptive Scheduling algorithm determines the time slot for packet transmission. Both theoretical analysis and simulation results show that the proposed protocol ensures better performance in terms of packet delivery ratio, average end-to-end delay and normalized routing overhead.

**Keywords**—Delay-sensitive data, Markovian Decision Process based Adaptive Scheduling, Opportunistic Routing, Digital Signature authentication.

## I. INTRODUCTION

IN wireless networks multicasting of delay sensitive data is widely used in many applications. Multicasting is the transfer of messages to multiple destinations simultaneously. A common requirement of such applications is that the information must be delivered to as many receivers as possible within certain time constraint [1]. Multicast wireless networks [2] mainly focus on reducing bandwidth and power consumption ensuring secure packet transmission and packet loss detection. In wireless networks, channels are lossy in nature [3] where packets may be lost during transmissions due to reasons such as channel fading [4], [5]. Hence network coding is done to ensure secure transmission. However network coding is susceptible to bogus packet injection attacks in an unfriendly environment. Thus an efficient authentication scheme is required. Secure transmission scheduling is more essential for reducing packet loss in WSN [6]. Digital Signature scheme has been proposed in [7] and [8]. All Scheduling algorithms will not recover the problem of attackers and bogus packet injection [9]. At any time-slot the packet must be transmitted in secure manner is very important in this proposed work.

## II. EXISTING SYSTEM

Opportunistic Routing in Multihop Wireless Networks has been proposed in [10] to avoid duplication of packets.

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However the optimal path value for each node with different path was not calculated. In [11] energy efficient Assistant Opportunistic Routing (AsOR) protocol which provides a method for selecting optimal value for each node is proposed. This scheme is not suitable for coded network. Null Key generation [12] to detect bogus packets helps in successfully decoding original packets. But the computational cost is very high for using the null key space properties to defend against pollution attack in wired-coded networks. An efficient key management scheme was proposed in [13] but was not suitable for multicasting delay sensitive data

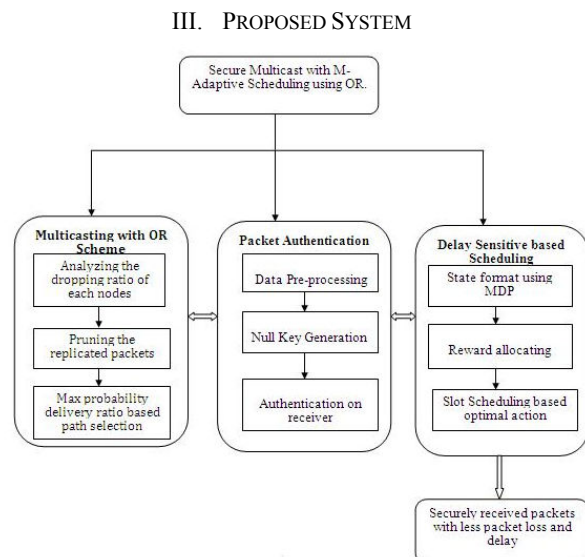


Fig. 1 Architectural Diagram

Fig. 1 shows the architectural diagram of the proposed protocol. Multicasting with Opportunistic Routing determines the best path. Packets are authenticated using null keys before transmission. Markov Decision based Adaptive Scheduling decides on the time slot to transmit the authenticated packets.

## IV. MULTICASTING WITH OPPORTUNISTIC ROUTING

In the proposed method we invent a procedure to find the drop ratio for each node in the network. The probability of delivery ratio has to be found to select the active forwarder for carrying out the bundles of packet to next node. The link with low delivery ratio is a weak link and will be discarded from the active path. The following three metrics are used to select the secure path.

- Packet delivery ratio, which is defined as the number of

sole multicast bundles which successfully arrive at all the receivers over the total number of bundles that are expected to be received

- Packet delivery efficiency, which is the ratio between the single bundles received by the receivers and the total data transfer generated in the network.

Equations to update the probability of delivery ratio is given as follows

$$P(a,b)=P(a,b)_{old}+(1-P(a,b)_{old}) \times A \quad (1)$$

$$P(a,b)=P(a,b)_{old} \times C_k \quad (2)$$

$$P(a,c)=P(a,c)_{old}+(1-P(a,c)_{old}) \times P(a,b) \times P(b,c) \times B \quad (3)$$

where  $P(a,b)$  denotes the delivery predictability of reaching node  $b$  from node  $a$  and  $A, B, C$  are initialization constants chosen from the range  $[1]$ . Each node maintains an  $m \times m$  matrix, with  $m$  denoted as the number of nodes in the WSN, where each row  $i$  records the delivery predictability of node  $i$  to other  $N-1$  nodes. Each node uses (1), (2) and (3) to update its own delivery predictability to other nodes.

- Average end-to-end delay, which is the average of the end-to-end packets delivery latency for each algorithm.

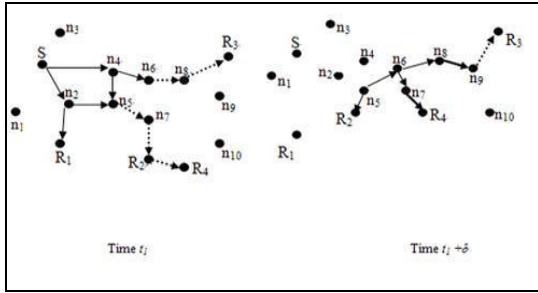


Fig. 2 Probability based OR scheme

Fig. 2 shows path selection based on Opportunistic routing.

#### V. PACKET AUTHENTICATION

The authentication scheme is inspired by null space originally proposed for defending against pollution attacks. Null key is embedded with transmitted packets. If the receiver identifies the null key then the packet is not a bogus packet [14], [2], [13]. Authentication process consists of the following three phases: Data Pre-processing, Null Key generation and Receiver side authentication.

##### A. Data Pre Processing

The network coding is applied to a batch of  $n - 1$  incoming packets, denoted by  $\{D_i\}_{i=1}^{n-1}$ . For secure transmission, each batch needs a signature packet, denoted as

$$S = M - 1 (hs (D_1 || \dots || D_{n-1})) \quad (4)$$

where  $M-1$  denotes the transmitter's signature using its private key,  $hs$  is hash function and  $D$  represents packet

fragment. By using Digital Signature Algorithm (DSA) the packets are signed and verified before sending it to the receiver thus ensuring security [4].

##### B. Authentication Using Null Keys

The receiver must differentiate between genuine coded packets from bogus ones injected by outsiders. By generating the null key packets, the transmitter optimally sends the null key packets to the receivers to filter out bogus packets.

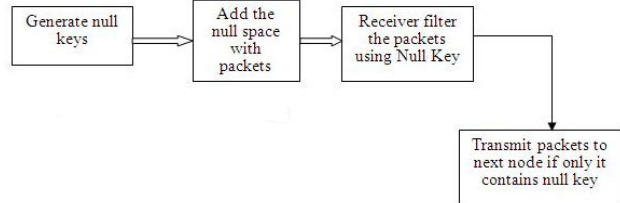


Fig. 3 Null Key Generation

##### C. Receiver Side Authentication

We implement the following steps for receiver side authentication.

Step 1. Check for valid values of nested hash function from the current batch. If not, verify the signature  $M-1(hs(v1-8))$  using the transmitter's public key  $K$ . Otherwise, check if it matches the one in new null key packet. The null packet is dropped if either  $v1-8$  does not match or the signature is invalid.

Step 2. Verify the authenticity of the received null key  $z_i$  using the authentication information along the path. For example, for null key packet  $K1$ , the receiver checks if

$$v1-8 = hs(hs(hs(hs(z1)||v2)||v3-4)||v5-8) \quad (5)$$

Step 3. Using the received null key, check all the received data packets to detect bogus packets, if any.

Step 4. Repeat Step 1 to Step 3 until it reaches the deadline. If the number of coded packets passed the authentication is larger or equal to  $n$ , decode the original data packets

$$\{D_i\}_n, i=1. \quad (6)$$

#### VI. MARKOV DECISION PROCESS BASED ADAPTIVE SCHEDULING

This section describes how the transmitter adaptively schedules transmissions (data packets and null keys), based on the network state [11], to maximize the network authentication rate. The network dynamics is modelled as a Markov Decision Process (MDP) and at each time slot the transmitter chooses an action from the action set to maximize the accumulative reward at the end of the transmission period. In particular, we specify the network dynamics by a six-tuple  $(S, A, P, r, T, \gamma)$ , where boldface letters refer to matrix or vector.

*Algorithm: Simulation-based Backward Induction Algorithm (SBIA)*

Input:  $S, A, T, \gamma$ .

Output:  $\pi^* = \{d(s_1), d(s_2), \dots, d(s_T)\}$

- 1: Initialize:  $t = T$ , set  $V^*(s_T) = 0$
- for all  $s_T \in S$
- 2: for  $t := T - 1$  to 1 do
- 3: for each state  $s_t \in S$  do
- 4: try all actions  $a_t \in A$  for iterations and calculate
- 5:  $V^*(s_t, a_t) = 1/\Delta \sum \Delta [r(s_t+1|s_t, a_t) + \gamma V^*(s_t+1)]$
- 6:  $V^*(s_t) = \max_{a_t \in A} \{V^*(s_t, a_t)\}$
- 7:  $d(s_t) = \arg \max_{a_t \in A} \{V^*(s_t, a_t)\}$
- 8: end for
- 9: end for

In MDP action set, three actions are identified, namely packet with null key, empty packet and packet with false data. The rewards are given for each node in the transmission path based on action chosen from the action set for successive move without time delay. Based on the rewards at various time slots the optimal policy will be generated to schedule the packets with maximum rewarded time-slots. MDP based Adaptive Scheduling (MAS) implementation of SBIA algorithm is applied to find the time-slot at which slot the packet has to be sent to reward the node based on chosen true action from MDP action set. This analytical function will reduce the time delay on receiver side and also increase the packet delivery ratio on fixed time-slot.

## VII. PERFORMANCE EVALUATION

The proposed protocol is compared with CodeOR network Coding scheme. CodeOR uses network coding in opportunistic routing without any scheduling. The metrics considered for comparison are as follows:

*Packet Loss Rate (PLR)* is a measure of number of packets lost given by

$$PLR = \text{Packet received/Packets sent by source} \quad (7)$$

Unsecure links lead to higher loss rate. As seen in Fig. 4 MAS and OR reduce loss rate considerably.

*Packet Drop Ratio (PDR)* is the relative amount of bundles of packets delivered from the learning history of all nodes. The drop ratio is given by,

$$PDR = (\text{Packet received by neighbor node/Packets sent by previous node}) * 100 \quad (8)$$

Fig. 5 shows that the novel approach of routing protocol reduces the packet drop ratio.

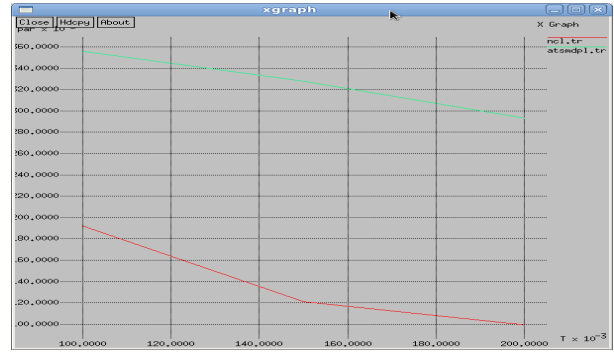


Fig. 4 Comparison Graph for Packet Loss Rate

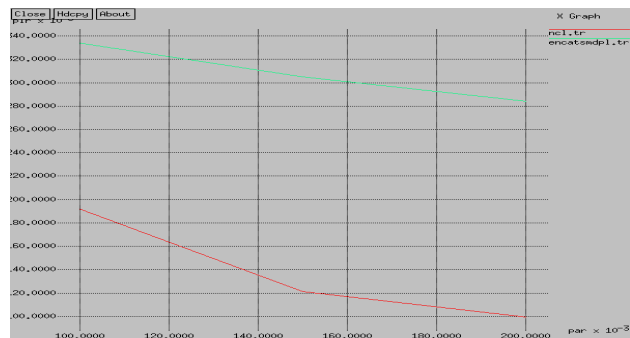


Fig. 5 Comparison graph for PDR

*Authenticated Packet Rate (APR)* is given by,

$$APR = \text{No. of packets authenticated/Total no. of packet in channel} \quad (9)$$

It is calculated as the number of packets authenticated with respect to null key received by the destination. The bogus packets are detected by using this metric. Hence as seen in Fig. 6 DS algorithm provides maximum protection for bundles of packets.

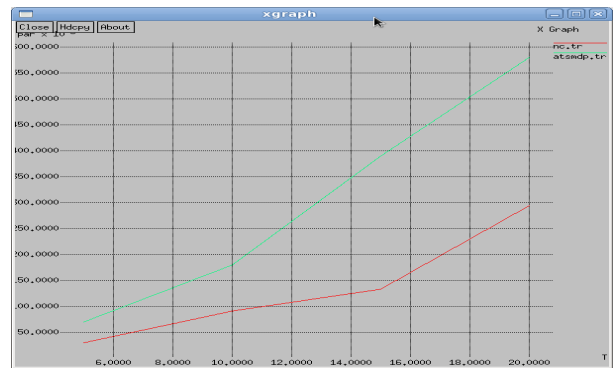


Fig. 6 Comparison graph for APR

*Probability of Deliverable Ratio (PPR)* is the expected ratio of delivery capability of a node along the transmission path given by,

$$PPR = 1 - PDR \quad (10)$$

Fig. 7 shows the comparison graph for PPR. OR and MAS help in reducing PPR.

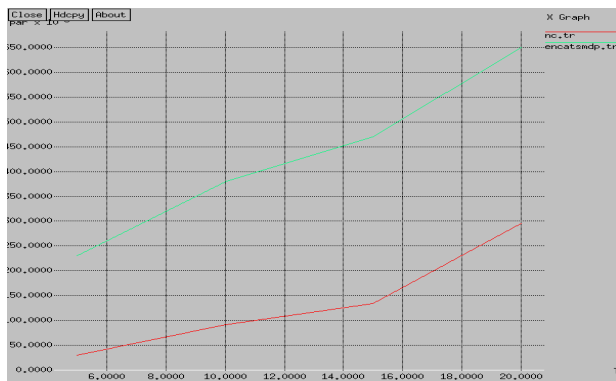


Fig. 7 Comparison graph for PPR

### VIII. CONCLUSION

In this study we have presented a probability-based routing scheme with Adaptive Scheduling to solve the multicast routing problem for WSNs. Simulations based on NS-2 have been carried out to verify the performance of the proposed scheme. To carry out and adopt the optimal transmission method we follow the MDP model and combine Opportunistic routing with Adaptive scheduling. Experimental results confirm that the proposed scheme outperforms Network coded scheme in terms of the packet's delivery-ratio and the standardized routing overhead. It also avoids flooding, pruning and reduces the traffic with very less amount of packet loss in WSNs.

As future work stochastic dynamic programming can be used as a model for sequential decision making when outcomes are uncertain. Energy efficiency in Opportunistic Routing protocol in WSN with advanced MDP scheduling scheme can be considered.

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