Optimization and Wireless Networks with Jamming Characteristics

N. Elamathi
Department of Computer Science
Trinity College for Women
Namakkal-637001, Tamilnadu, India
emathi@yahoo.com

C. Chandrasekar
Department of Computer Science
Periyar University
Salem-636 011, Tamilnadu, India
ccsekar@gmail.com

Abstract

In Wireless 802.11 networks, Multiple-path source routing allows data source node to distribute the total traffic among the possible available paths. However, in this case jamming effects were not considered. Recent work has presented jamming mitigation scheme, anti-jamming Reinforcement System on 802.11 networks by assessing physical-layer functions such as rate adaptation and power control. Rate adaptation algorithms significantly degrade network performance. Appropriate tuning of carrier sensing threshold allows transmitter to send packets even on jam that enable receiver to capture desired signal. Efficient schedules need to be investigated for redundant transmission to perform well in presence of jammer. In this paper, the proposal in our work presents an Efficient Time and Transmission Schedule Scheme for wireless 802.11 networks in presence of jamming that guarantee low waiting time and low staleness of data. Schedules are optimal even jamming signal has energy limitations. Each packet is encoded by an error-correcting code (Reed-Solomon). Reed solomon code allow schedule to minimize waiting time of the clients and staleness of the received data. Jammers have restrictions on length of jamming pulses and length of intervals between subsequent jamming pulses.

Keywords: Transmission Schedule, 802.11 Network, Jamming characteristics.

1. Introduction

Wireless 802.11 networks were designed under the assumption that all nodes are interested in transmission of data, and follow the rules of the protocol regarding when to send and when to permit other nodes to send. Jamming point-to-point transmissions in wireless 802.11 network can produce negative effects on data transport through the network. The effects of jamming at the physical layer provides an effective denial-of-service. The simplest methods to avoid jamming at the physical link layer is to provide solutions such as spread-spectrum or beaforming. It forces the jammers to extend a greater resource to reach at the desired goal. Spread-spectrum techniques are methods by which a signal (e.g. an electrical, electromagnetic, or acoustic signal) generated in a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth. These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference noise and jamming, to prevent detection, and to limit power flux density.

However, recent work has proposed that intelligent jammers can create cross layer protocol information to jamming attacks which in turn reduces the resource expenditure. It targets certain link layers and MAC representations and also link layers error detection and error correction protocols. So more sophisticaed anti-jamming traffic methods have proposed in the higher layer to name a few are channel surfing. Channel surfing is the practice of quickly scanning through different television channels radio frequencies in order to find something interesting to watch or listen to. Modern viewers, who may have cable or satellite services beaming down dozens if not hundreds of channels, are frequently caught channel surfing. It is common for people to scan channels when commercial broadcasters switch from a show over to running advertisements.

The majority of anti-jamming techniques consider mainly diversity. It may employ multiple frequency bands, different MAC channels or multiple routing paths. To make effective use of this routing diversity, each source node must be able to make an intelligent allocation of traffic across the different available paths while also considering the potential effect of jamming on the resulting data throughput. Anyhow, the jamming at each network node depends on a number of unknown parameters like the strategy used by the individual jammers and the relative location of the jammers and the relative location of the jammers with respect to each transmitter-receiver pair.

In this paper, we introduce an efficient Time and Transmission schedules for wireless 802.11 networks in presence of jamming that guarantee low waiting time and low staleness of data. Proposed Time and Transmission schedule scheme is optimal even jamming signal has energy limitations. Each packet is encoded by an error-correcting code (Reed-Solomon). Reed solomon code allow schedule to minimize waiting time of the clients and staleness of the received data. Jammers have restrictions on length of jamming pulses and length of intervals between subsequent jamming pulses.

The paper is structured as follows. In section 2 Literature review are discussed. Section 3 Efficient Time and Transmission Schedule for 802.11 Networks with Jamming Characteristics. In section 4 Performance Evaluation on Efficient Time and Transmission Schedule Scheme. Section 5 Results and Discussion on Efficient Time and Transmission Schedule Scheme Section 6 deals with the conclusions.

2. Literature review

The Widespread proliferation of IEEE 802.11 wireless networks makes them an attractive target for saboteurs with jamming devices [1]. They provide network access for both mesh and conventional clients. The focus of designing reliable UWA networks that is capable of transferring data from a variety of sensors to on-shore facilities [2]. Major impediments to the design of such networks were considered, which are: 1) severe power limitations imposed by battery power; 2) severe bandwidth limitations; and 3) channel characteristics including long propagation times, multi path, and signal fading.

In [3], investigated the problem of denial of service against data packets (e.g., IP packets) transmitted over WLAN protocols (i.e., IEEE802.11 and Bluetooth). It is easy to jam such communications at an energy cost [4] that is much lower than the transmitter's cost. Such attacks cannot only prevent communication within large areas [5] for long periods of time but can also lead to other more elaborate and coordinated attacks such as partitioning of a multihop ad hoc network or forcing packets to be routed over chosen paths [6].

A different defense strategy [7] involves sensors trying to out-compete the jammer by employing error correcting codes and increasing the node transmission power. Both evasion and competition strategies [8] are at an early stage of investigation by the community [9], and as these techniques mature an important area for study was understood and classifying the scenarios where one defense strategy is advantageous over another.

In [10], jamming-aware source routing traffic allocation methods in wireless mesh network. It maps lossy network flow optimization algorithm [11] to the asset allocation algorithm with the help of portfolio selection theory. Using the distributed algorithm multi-source multi-path optimal traffic allocation was computed for the intended source nodes. Distributed algorithm was precisely based on the decomposition in network utility maximization. The existing work also allows individual network nodes to locally characterize the jamming impact for the aggregate of source nodes [12]. As there is an uncertainty in achievable traffic rates portfolio selection theory allows data sources to balance the expected data throughput with the available value.

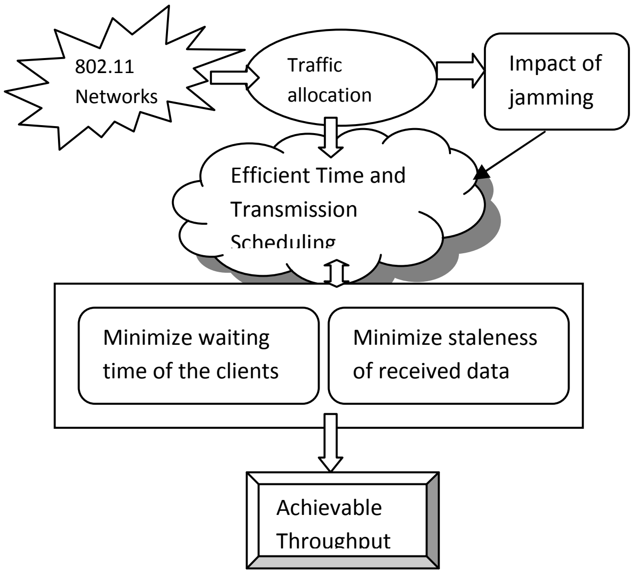

Figure 1 Architecture diagram of Efficient Time and Transmission Scheduling Scheme

3. Efficient Time and Transmission Schedule for 802.11 Networks with Jamming Characteristics

The proposal work presents Efficient Time and Transmission Schedule for 802.11 Networks with Jamming Characteristics. The characteristics of jamming traffic are measured. The impact of resource utilization on jamming traffic is also identified. For all the resources, transmission schedule is assigned. The data source node for optimal multi-path traffic allocation is identified and localized. The use of scheduled resource utilization improves the data delivery rate of the source nodes. Simulations are carried out for the Time and transmission schedule for 802.11 networks which is made on multiple traffic rate variances . Jamming characteristics for the resource utilization at the local source node are also evaluated.

The traffic is distributed among the available paths in the network. It also involves empirical jamming statistics. In result the impact of jamming is felt in the distribution of traffic network. 802.11 Networks are applicable to different scenarios. The job of source node is to make the allocation in an intelligent manner. It is also made available across different paths. The distribution of traffic provides with multiple source nodes for jamming and with multiple routing paths. The impact of jamming is characterized in the distribution of traffic. Proposed Time and Transmission schedule scheme (as shown in fig 1) is optimal even jamming signal has energy limitations. Each packet is encoded by an error-correcting code (Reed-Solomon). Reed solomon code allow schedule to minimize waiting time of the clients and staleness of the received data. Quadratic term is expressed in throughput due to the uncertainty involved in estimate. While formulating the multi-path traffic allocation risk-aversion parameter is the main factor considered.

3.1 Jamming characteristic

The jamming model must be accurate enough to capture the characteristics of practical jammers, and, at the same time, be simple enough for the optimization of network protocols. It has been recognized that the power supply is the most important limitation for the majority of practical jammers. A typical jammer is powered by a battery, which can be recharged from an external source, such as a solar cell array. The source node determines its own traffic allocation with the help of minimal message passing between sources. The goal of the jammer is to disrupt the normal operation of the broadcast system, which results in high waiting time and excessive power consumption of the clients. To that end, the jammer sends active signals over the channel that interfere with the signal sent by the server A set of sources with estimated parameters compensate on the presence of jamming on network traffic flow in distributed formulation for jamming-aware traffic allocation.

3.2 Efficient Time and Transmission Schedule

Multiple resources are allocated for difference MAC channels, multiple routing paths and multiple frequency bands. Risk-aversion is achieved for multiple resources. Resources are allocated to less risky paths than highly risky paths. Trade-off is maintained between expected throughput and estimation variance. It also varies with time or for various types of data. The data is delivered in the form of packets, each packet captures the current state of the information source. We assume that each packet includes exactly P information symbols. We also assume that transmission of P symbols of over the channel requires one unit of time.

We enumerate the packets, according to the time of their transmission. Each packet is encoded into a message that contains at least P symbols by using an error-correcting code, such as a Reed-Solomon [16]. The encoding ensures that any P symbols of the message are sufficient in order to reconstruct the original message.

A schedule is a sequence $\{t_{1,} t_{2,} ....t_m\} \geq 1$, such that t_m is the amount of time required to transmit message m . Note that the length of message m is equal to $t_m P$.

A schedule $\{t_1, t_2 ...\}$ can also be defined by its transmission sequence $\{TS_1, TS_2 ...\}$, where TS_m represents the starting time of the transmission of message m , i.e.,

$$TS_1 = 0 \text{ and } TS_m = \sum_{n=1}^{m-1} t_n \text{ for } m > 1. \qquad (1)$$

In the first schedule, each encoded message contains $t.P$ symbols. Thus, the schedule transmits each message is transmitted over an interval of t time units and generates a new packet at times $0, t, 2t....$. A wireless client begins to listen to the wireless channel upon a request for new information. In order to satisfy the request, the client must receive at least P symbols from the currently transmitted message. If the client fails to receive P symbols from the current message, it continues to listen to the channel, until it receives at least P symbols from one of the subsequent messages.

They are two key performance characteristics of the schedule: the expected waiting time and the maximum staleness of the received data.

Waiting time (S)): Let S is a broadcast schedule. Suppose that the client's request was placed at time t . Let k be the number of the message currently transmitted over the channel. Let t' be the first time the client receives at least P symbols from a message $k', k' \geq k$. Then, the waiting time of the client is defined as

$$WaitingTime(S) = t' - t \qquad (2)$$

Following [12] we assume that the clients' requests are distributed uniformly over time. Accordingly, the *Expected Waiting Time* of the clients is defined as follows:

$$\text{Expected Waiting Time (S)} = \lim_{w \to \infty} \frac{1}{w} \int_0^w WaitingTime(S) dw \qquad (3)$$

The waiting time is an extremely important parameter for many time-sensitive applications. In addition, it is closely related to the amount of power spent by the client to obtain the information. The staleness of the data is defined to be the amount of time that passes from the moment the information is generated until it is delivered to the client. The staleness captures the quality of delivered information, because in dynamic settings the information becomes less and less relevant with time.

Staleness(S): Suppose that the client's request was placed at time t. Let k be the number of the message currently transmitted over the channel. Further, let $k' \geq k$ be the first message for which the client receives at least p symbols. Then, the staleness of the data is defined to be

$$Staleness\ \ (S) = t_{k'} - t \qquad (4)$$

Suppose that a client arrives at time ts. The number of symbols received by the client from the currently transmitted message is equal to

$$k_t = ([\frac{ts}{t}]t - ts)P \qquad (5)$$

If $k_t \geq P$, then the client will be able to decode this message, hence its waiting time is zero. Otherwise, the client needs to wait for the next message, hence its waiting time is nt. It is easy to verify that if the clients are distributed uniformly over time, the expected waiting time is

$$\frac{P}{2k} = \frac{1}{2t} \qquad (6)$$

While redundant transmission improves the expected waiting time of a schedule, it comes at a price in terms of the staleness of the received data. Indeed, if $k_t \geq P$, then the packet received by the client at time *ts*, was generated in time

$\left\lfloor \frac{ts}{t} \right\rfloor t$, hence the staleness of the data is

$$ts - \left\lfloor \frac{ts}{t} \right\rfloor t \qquad (7)$$

On the other hand, if $k_t < P$, then the client will get a new packet, hence the staleness is zero.

The example demonstrates that there exists a certain trade-off between waiting time and staleness in data broadcast systems. While finding a schedule that has minimum waiting time subject to a staleness constraint in a not-jammed channel is a relatively easy task, this task is much more complicated in the presence of a jammer.

3.3. Algorithm for Time and Transmission Schedule

Pseudo code of the Time and Transmission Scheduling algorithm is shown in below.

Input: Packets includes exactly *P* information symbols

Output: Transmission schedule S

t ← Time slot when the 1st packet arrives

while (unscheduled transmission) do

T← set of transmissions that are ready at slot t

Channel ← 0 **for** each T

i. T_w ← Calculate Waiting Time from equation (2)
ii. T_{EW} ← Calculate Expected Waiting Time from equation (6)
iii. D_s ← Calculate Staleness data from equation (7)

while (($T_{EW,}$ D_s) = = low) do

Tr ← Transmission with low Waiting Time and Staleness data

Tr' ← Transmission with shortest deadline in Tr

if (Tr' misses deadline)

then return unschedulable

(ch) ← Tr'

ch ← ch + 1

end

t ← t + 1

end

As shown in the pseudo code, Input is taken as Packets includes exactly *P* information symbols and Outputs the Transmission schedule S. For any transmission, the time time slot t is assigned. The set of unscheduled transmission T is taken with the time slot t. Initially, Channel offset ch is assigned to zero. For each Transmission T, Waiting Time, Expected Waiting Time and Staleness of data is calculated by using the equation (2), (6) and (7) respectively. If expected Waiting Time and Staleness of data is low then while loop is executed. For any transmission T, while scheduling at some slot t, if the algorithm determines that Tr' (deadline of Tr) is already less than t, then the algorithm terminates as it has failed to find a feasible solution. Otherwise, Tr' is assigned slot t and channel offset ch, the schedule is recorded as S[ch] = Tr' which is an final output.

4. Performance Evaluation on Efficient Time and Transmission Schedule Scheme

In this section, we simulate various aspects of the proposed Time and Transmission scheduling algorithm, we evaluate the results of simulation using NS-2. For this purpose, we compared our algorithm with the ARES. The proposed NIRA using IRDM is evaluated in an efficient manner using NS2 simulator. Initially the experiment is evaluated with 100 nodes in a flat area of 100 * 100 m2. The nodes' incoming time (sec) is noted as t1, t2….tn. The routing discovery mechanism is taken for routing information to identify the route path from source to destination. The simulation results show that it takes 850 secs to transmit the packet from source to destination by choosing the path efficiently. The compared aspects were

i. Achievable Throughput:
ii. Traffic allocation
iii. Execution time

Achievable Throughput: Average rate of successful message delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node

Traffic allocation: Transmission schedule is measured as percentage of cases the algorithm is able to find a feasible schedule among the total number of cases considered. The maximum number of traffic allocated at a field device at any point of time during the schedule.

Execution time: This is the total time required to create a schedule for all packets generated within T (least common multiple of periods) time slots.

5. Results and Discussion on Efficient Time and Transmission Schedule Scheme

Simulation works are carried out with NS2 with achievable throughput using traffic allocation problem based on the resulting data throughput. The available paths are characterized based on throughput. The traffic rates incurred are non-negative and also define convex space. Due to the jamming characteristics traffic rate is reduced in the receiving node which again imposes stochastic constraint. The delay time is bound in traffic distribution algorithm. The traffic variance is computed during regular intervals. Exponential Weighted Moving Average (EWMA) method is applied to update traffic variance. Bandwidth utilization is low bound without loss of bandwidth. The performance metrics measured are Achievable Throughput, Traffic allocation and Execution time.

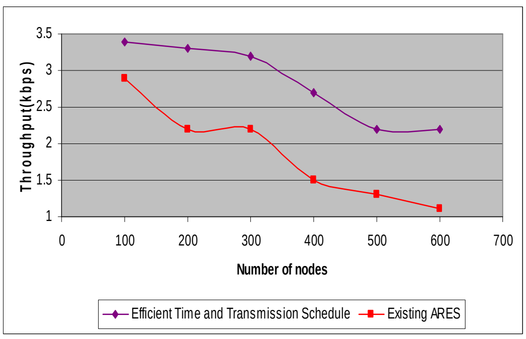

Figure 2 Throughput

Network throughput is the average rate of successful message delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot. The figure 1 shows the output of the simulation by varying the number of nodes with in Wireless 802.11 networks. As the number of nodes increases, throughput increases. By comparing it with existing Jamming-aware source routing traffic allocation model, our Priority based resource utilization scheme is effective.

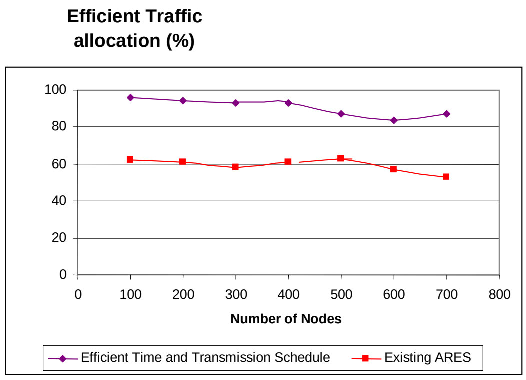

Figure 3 Efficient traffic allocations

Figure 3 depicts the resultant graph of efficient traffic allocation on Proposed Time and Transmission Schedule and Existing ARES. For each simulation nodes can be changed from 100,200…. 700. Traffic allocation ratio is measured for each simulation. If number of nodes will be increased, Traffic allocation ratio gets automatically decreased in both Proposed Time and Transmission Schedule and Existing ARES. For example, In Proposed Time and Transmission Schedule scheme, nodes from 100 to 400, Traffic allocation ratio is 93 to 96 % and nodes from 500 to 700 traffic allocation ratio gets decreased to 84%. The above performance graph shows the Proposed Time and Transmission Schedule scheme outperforms well compared with ARES.

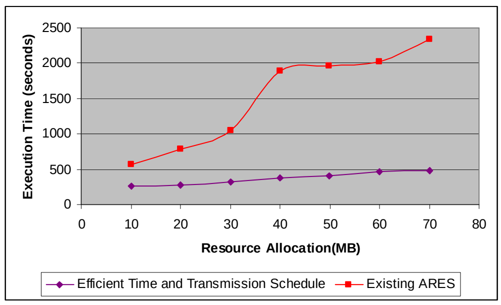

Figure 4 Execution Time

The execution time of the Proposed Time and Transmission Schedule scheme and Existing ARES increases sharply with the increase of workload increases. Resource is allocated from

10 MB to 70 MB. Figure 4 shows that the execution time of Proposed Time and Transmission Schedule scheme is relatively low compared with ARES.

The simulation results show that our proposed Time and Transmission Scheduling scheme performs well in terms of Achievable Throughput, Traffic allocation and Execution time.

6. Conclusion

In this paper, we have implemented an Efficient Time and Transmission schedule scheme for wireless 802.11 networks in presence of jamming. Proposed Time and Transmission schedule scheme guarantee low waiting time and low staleness of data. Schedules were optimal even jamming signal has energy limitations. Reed-Solomon error-correcting code has been used to encode an each packet while transmission that allow schedule to minimize waiting time of the clients and staleness of the received data. Jammers have restrictions on length of jamming pulses and length of intervals between subsequent jamming pulses. Experimental simulations were conducted to evaluate our Time and Transmission schedule algorithm. Simulation results show that our proposed Time and Transmission Scheduling scheme performs well.

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N. Elamathi received her Bachelor’s degree from the University of Bharathidasan ,Trichy, Tamilnadu in 1995, M.sc (C.S) from the University of Alagappa University, Karikudi in 1998, and M.Phil(C.S) from the University of Manonmaniam sundaranar university, Tirunelveli in 2003.

Dr. C. Chandrasekar received his Ph.D. degree from Periyar University, Salem. He has been working as Associate Professor at Dept. of Computer Science, Periyar University, Salem, Tamil Nadu, India. His research interest includes Wireless networking, Mobile computing, Computer Communication and Networks. He was a Research guide at various universities in India.