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Reducing Starvation in Multi-Channel Protocols Through Enhanced AMCP

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***Abstract*---The multi-channel protocols are determined to have more throughput when compared to single-channel protocols. Asynchronous Multi-Channel Co-Ordination protocol (AMCP) is devised to address the starvation in multi-channel protocols by having an approximate lower-bound on the throughput of any flow in arbitrary topology. We here determine that AMCP can be enhanced by modeling per-flow throughput. The determined methodology has been found to have higher per-flow throughput than IEEE802.11 and MMAC**

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Key words:- ***AMCP, MMAC, Multi-Channel.***

I. INTRODUCTION

The previously determined protocols like IEEE 802.11 DCF are used to produce unfairness when applied to multi-hop wireless networks. The presence of starvation can be overcomed by scheduling the transmissions that are interfering over multiple orthogonal channels. The presence of starvation occurs because of the lack of channels and transceivers. Recently developed wireless cards have a single transceiver and thus support a limited number of orthogonal channels.Based upon the transceiver and channel constraints, scheduled access methods [1], by co-coordinating transmissions across multiple channels, the starvation can be addressed in an operational manner. The infrastructure support required here is GLOBAL TIME SLOT SYNCHRONISATION (TDMA). Previous multi-channel MAC protocols have shown increased aggregate network throughput, but they do not provide mechanisms to prevent starvation in multi-hop wireless networks. We devise that without proper co-ordination of transmissions, when numbers of channels are increased, the aggregate throughput is increased but certain flows still receive zero throughput. In our paper, first the concept of starvation is discussed in single channel CSMA protocols due to mis-aligned transmissions that cause collisions at the flow's receiver. Multi-channel wireless technologies abort the starvation by transferring the misaligned transmissions to other channels.After this situation, achieving it is difficult when single channel is considered; one node can transmit or receive at a time.Although packets can be sent on different channels, these transmissions in multi-channel system are still not aligned which thus create the following multi-channel co-ordination problems:

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1) Control packets sent on a dedicated channel fail to inform the neighboring nodes that are currently communicating on a different channel.
2) Control packets that are intended for a certain receiver may not sustain because the receiver is operating currently on a different channel.

These problems may also lead to starvation if they cannot be addressed properly. A predefined solution is to use a dedicated control channel or transmit both control and data information on all the available channels. AMCP utilizes a dedicated control channel to address both single-channel and multi-channel co-ordination problems and effectively alleviate starvation in a multi-hop wireless network[1].To overcome the inference by the control channel, we compute the maximum number of data channels those can be supported by a control channel in terms of the protocol parameters. This allows us to perform sizing appropriately based upon the control channel capacity.

Now we derive an approximate lower bound on the throughput of AMCP flow in an arbitrary topology. The proposed technique is to develop a hypothetical, low-throughput scenario on the control channel and to model the impact of aggregate channel hopping pattern of the interfering flows. The lower bound relies upon system parameters and the number of intermediate interfering nodes within the neighborhood of each flow. By achieving extensive simulations, we determine the characteristics of AMCP in multi-hop network scenarios. We devise the AMCP and analyze how does AMCP addresses multi-channel co-ordination problems. We determine the discrepancy of AMCP due to delay caused by channel switching.

II. STARVATION OCCURRENCE IN VARIOUS SCENARIOS & ADDRESSING STARVATION IN MULTI-CHANNELS

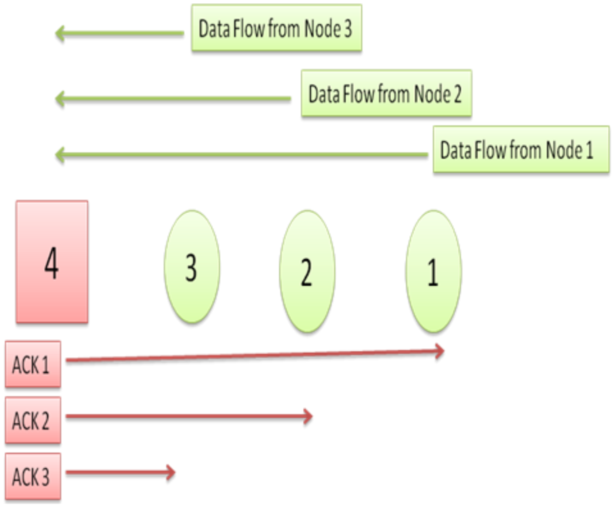

Fig 1: Starvation in wireless mesh networks

To explain how starvation occurs in a network we consider the above example which consists of 3 nodes and a gateway node. As the nodes which are closer to the gateway node i.e.., node 4 will first engages the channel for the transmission of packets. After one successful transmission the node will resets its contention window and again ready to start its transmissions. As the remaining nodes in a network mostly node 1 will occur starvation. The node 1 will not get a chance of using the network bandwidth as a result it starves.

A. Starvation scenarios

a) Carrier sense starvation

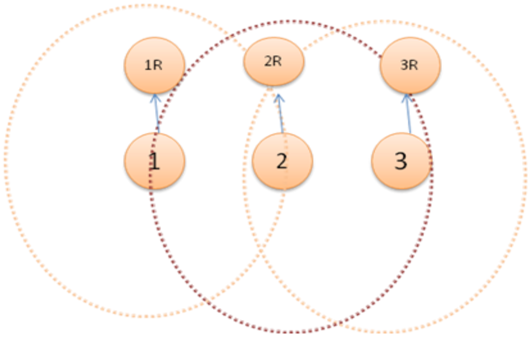

Fig 2:Carrier sense starvation in a network having three nodes

Carrier Sense Starvation results in low transmission opportunities due to indigenous unfairness of IEEE 802.11 DCF protocol. The 3 flows in the above figure shows the transmission ranges of 3 nodes, where node 2 can sense both nodes 1 and 3, Node 1 and 3 cannot sense each other. The transmissions of nodes 1 and 3 can overlap for a sustained time. As a result node 2 always finds a busy channel and freezes its back-off counter.

b) Hidden node starvation

The hidden node starvation occurs when there are concurrent transmitters outside the carrier sensing range of a transmitter node but within the interference range of its receiver node. As shown in the above figure node 2 cannot sense transmissions of node 1, but it can interfere with its receiver node 1R. so the packets sent by node 1 will be lost at node 1R and the flow 1-1R will be starved. It should be observed that if nodes 1 and 2 are hidden to each other then both flows can still content the channel fairly and no single one is starved.

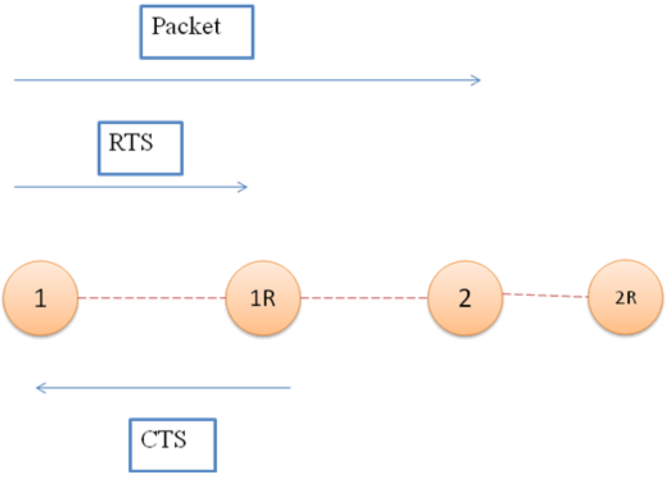

Fig 3: Hidden node starvation in a network having two nodes

c) Asymmetric sense starvation

Asymmetric sense starvation is caused by heterogeneous transmission power levels, carrier sense thresholds or asymmetric channel conditions among pairs of transmitter nodes. As per the above figure, the node 1 cannot sense node 2, but node 2 can sense node 1. As a result the transmissions from node 1's ongoing transmissions due to hidden node. . Moreover, node 1 always finds the channel to be idle and can access the channel whenever it has packet to send, while node 2 has to freeze its back-off counter when it detects node 1's transmissions.

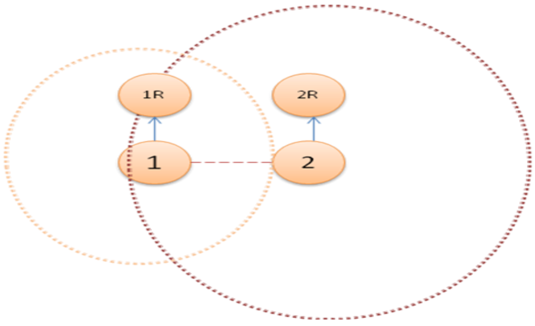

Fig 4:Asymmetric starvation in a network having two nodes

Therefore asymmetric sense starvation is a combination of hidden node and carrier sense starvation.

B. COUNTER STARVATION PROBLEM

The "Counter Starvation" problem is an unfair problem among TCP flows with different hops away from the gateway node or BS. As per the below fig, There are two mesh nodes, 0 and 1, which are located one hop and two hop away from the BS respectively. Mesh nodes 1 and BS are hidden from each other, because they cannot sense each other. Both node 0 and node 1 receive TCP flows from the BS at the same time. It is a common situation in WMNs.

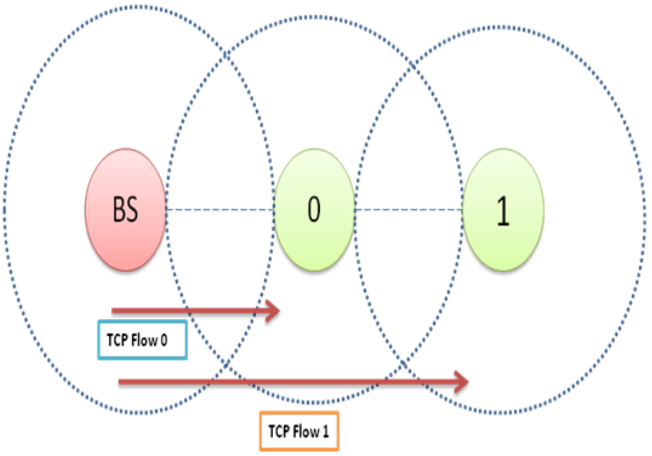

Fig 5: Typical Topology of Wireless Mesh Network

We consider a typical WMN topology in which TCP0 and TCP1 flows are transmitted from BS to nodes 0 and node 1 respectively. We calculate throughput, TCP congestion windows and delays of these two TCP flows and check which node suffers from starvation.

III. AMCP OVERVIEW

(i)Single radio transceiver
    (a)Node can either send or receive on a single channel at a time
(ii)Dedicated CONTROL channel (solution 2)
    (a)1 CONTROL channel
    (b)N DATA channels
(iii)Data structure
    (a)N-entry channel table
(iv)avail_bit: 0 or 1
(v)avail_timer
(vi)Prefer : 0 to N

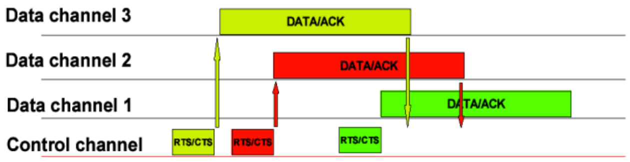

Fig 6:Representing data flow in AMCP protocol

(i)RTS/CTS

(a)Sender and receiver negotiate on common available channel x.

(b)Neighboring nodes that overhear set the channel status.

(ii)After RTS/CTS, sender and receiver switch to channel x

(iii)After data transmission, sender and receiver switch to control channel

(iv)Sender and receiver start timer and set all channels unavailable except x

(v)Contend for x immediately / contend for other data channels after timer expiration.

IV. RELATED WORK: AMCP EVALUATION FOR INCREASED THROUGHPUT.

A. AMCP PERFORMANCE IN MULTI-CHANNEL CO-ORDINATION PROBLEMS.

Computation of the conditional packet loss probability. To compute the throughput of flow Aa in the hypothetical, low-throughput scenario, we first need to compute the collision probability p when node A attempts to transmit an RTS packet to a. Similar to [4], we refer to p as the conditional collision probability.

Let X(t) be the Poisson process that represents the number of successful control packet arrivals of the N interfering nodes, given a starting point in time. Let α be the arrival rate of control packets and T be the arrival interval. Note that α is a deterministic value and T is a random variable.

We assume nodes can always find a data channel to transmit a data packet upon successful RTS/CTS exchange. The arrival rate α of X(t) is given by:

$$\alpha = \frac{N}{T_d + T_r + T_c} . \qquad (1)$$

Since X(t) is a Poisson process, any interval T between two successive control packet exchanges of the interfering flows is exponentially distributed with the following :

$$FT(t) = P(T \le t) = 1 - e^{-\alpha t} . \qquad (2)$$

The RTS/CTS exchange between A and a will fail if it cannot fit within an idle gap $T - (Tr + T c)$ between two successive control packet exchanges. This corresponds to the event $T - (Tr + T c) < Tr$ (or $T < 2Tr + T c$), which occurs with probability

$p=FT(2Tr+Tc)$.

Combining with Equations(2)and(3),

we derive the final expression for the conditional packet lossprobability

$$p{:}p = 1 - e^{-(2T_r + T_c)} T_d + T_r + T_c . \qquad (3)$$

B. Throughput computation

We compute the throughput of the tagged flow Aa using a general model for backlogged flows sharing an 802.11 multi-hop network introduced in [13]. In that model, the channel view of each node comprises of a sequence of time intervals that correspond to 4 different states:

(i) idle channel;
(ii) channel occupied by successful transmission of the tagged station;
(iii) channel occupied by a collision of the station;
(iv) busy channel due to activity of other stations, detected by means of either physical or virtual carrier sensing (the NAV). The time intervals during which the station remains in each of the four states above are denoted by σ, Ts, Tc, and Tb, respectively.

According to the model in [13], the throughput of the tagged flow Aa is given by:

$$TP = \tau(1-p)\bar{T}s + \tau p\bar{T}c + (1-\tau)(1-b)\sigma + (1-\tau)\, b\bar{T}b \quad (4)$$

where τ is the probability that the node attempts to send a packet after an idle slot, b is the probability that the channel becomes busy after an idle slot due to activity of other nodes and p is the conditional packet loss probability.
The probability τ is a deterministic function of p and is given by

$$2q(1-p^{m+1})/\tau = q(1-p^{m+1}) + W0 \quad 1-p-p(2p)^{m'} \quad 1+p^{m-m'}q \qquad (5)$$

where q = 1 − 2p, W0
is the minimum window size, m is the maximum retry limit, and m' is the back off stage at which the window size reaches its maximum value. The average durations $\bar{T}s$ and $\bar{T}c$ are fixed and can be found in [4].
In this hypothetical scenario, the transmitter node A does not defer its transmission due to the activity of other nodes. Setting b=0inEquation((5))yields: Using Equations (3) and (5), in Equation (6), we can now compute the throughput of the tagged flow in the hypothetical scenario which serves as a lower bound approximation on the throughput achieved by any flow in an arbitrary topology as a function of number of interfering flows and system parameters.

C. Lower bound validation

We now validate the approximate lower bound with simulations obtained with ns. Both RTS/CTS packets and data packets are transmitted at 2 Mbps. We vary the number of flows N and place them in a 700m × 700m area such that they belong to the same contention region. This means that only one flow can transmit successfully at a time, however it is not necessary that all transmitters or receivers are within range. For each N, we generate 10 data points each corresponding to the minimum rate achieved by a different contention region. Fig.6 shows the minimum rates as data points and the lower bound as the analytical curve, as computed by our model. We observe that in general the minimum rates are greater than the lower bound while in several cases the bound is tight.

PARAMETER	VALUE
SIFS	10 µs
DIFS	50 µs
EIFS	364 µs
σ	20 µs
BasicRate	2 Mbps
DataRate	2 Mbps
PLCP length	192 bits @ 1 Mbps
MAC header (RTS,CTS,ACK,DATA)	(20,14,14,28) bytes @ BasicRate
Packet size	1000 bytes
(CW min, CWmax)	(31,1023)
Retry Limit (Short,Long)	(7,4)
Channel switching delay	224µs
MMAC ATIM window	20ms
MMAC Beacon interval	100ms

Table 1: MAC LAYER PARAMETERS

V. RESULTS

AMCP can be employed to overcome the multi-channel co-ordination problems. The throughput of AMCP can be enhanced by modeling the per-flow throughput. The throughput of AMCP is calculated using above Poisson equation.

Network Simulator version2 is used for generating a wireless mesh topology and reduction of starvation in that topology.

- The wireless mesh network generated using NAM(network animator) is:

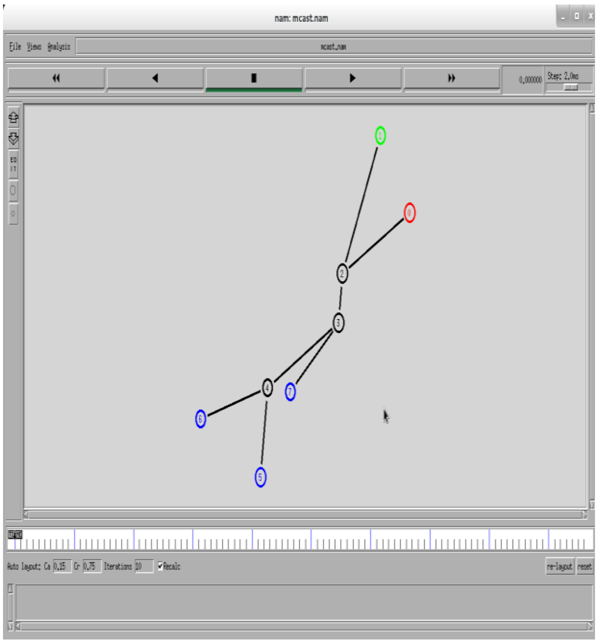

Fig 7: Construction of a network topology using NAM

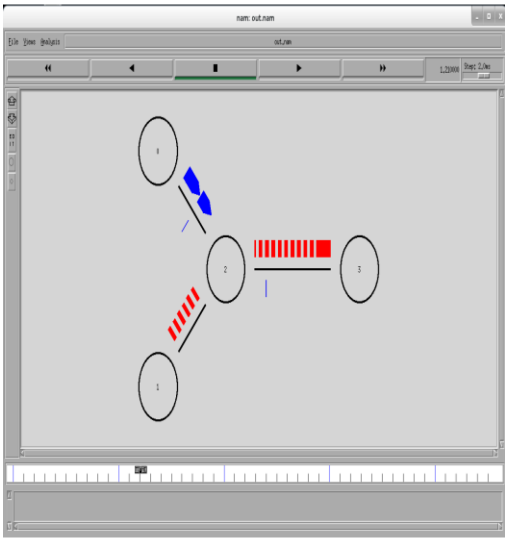

Fig 8: Starvation at node0

- Starvation of nodes 0 and 1: (shown in Nam Figure)
- After starvation occurred it is reduced using AMCP protocol.The throughput of AMCP, MMAC, IEEE802.11 are compared in the graph which is generated using GNUPLOT.

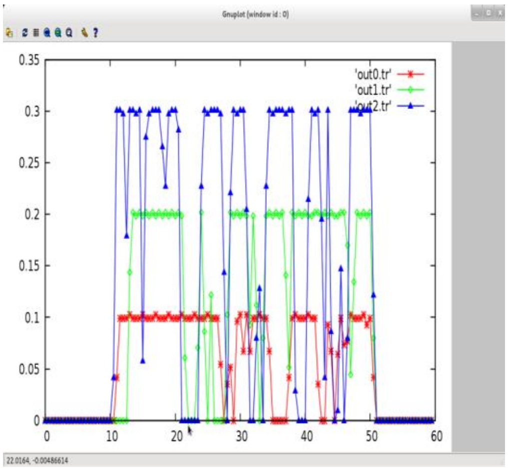

Fig 9:comparison of throughputs of AMCP,MMAC,IEEE802.11.

The graph shows three differently colored curves out0.tr, out1.tr, out2.tr which represent AMCP(BLUE),MMAC (GREEN),IEEE802.11(RED) respectively.

The throughput rate of AMCP protocol is higher when compared to MMAC and IEEE802.11 as shown in the graph. Hence we can conclude that using AMCP we can reduce starvation by increasing the throughput rate.

VI. CONCLUSION

We propose a procedure to reduce the extent of starvation. This improves fairness of mesh nodes that have successfully transmitted a data packet should not be permitted to transmit more data packets aggressively. By delaying the transmission of successive packets we are able to reduce the degree of starvation. This effect is achieved by adapting AMCP protocol.

Overall Throughput is increased and Delays in the network are mitigated. Bandwidth utilization is more compared to the existing system.

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