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OPTIMAL CHANNEL ALLOCATION WITH IDLE TIME USAGE (OCA-ITU): ADAPTIVE CHANNEL SCHEDULING STRATEGY FOR 802.11 BASED WIRELESS LOCAL AREA NETWORKS

Macha Sarada[1] and Avula Damodaram[2]
[1]MIS for Women, Khammam, Telangana State, India
[2]SV University, Tirupathi, Andhrapradesh, India
E-Mail: sarada.macha@gmail.com

ABSTRACT

This manuscript explores a novel channel-scheduling algorithm for varying size windows transmission in 802.11 Wireless Local Area Networks. The objective of the proposal is to achieve maximum throughput and minimal transmission loss and fair channel usage. The critical factors considered to schedule a channel are optimal bandwidth and idle channel availability. The proposed scheduling strategy is a hierarchical approach of three levels. The optimal idle channel allocation, optimal multiple idle channels allocation and optimal multiple channels with considerable transmission intervals allocation are the objectives of the respective levels of the scheduling hierarchy of the proposed algorithm. The introduction of the WLAN and channel scheduling associated literature, detailed exploration of the proposed channel scheduling strategy and performance analysis by simulation study presented in this article. The experimental study is evincing the scalability and robustness of the proposal in the context of maximizing throughput and minimizing the transmission loss. The performance analysis compared the proposed model with contemporary scheduling strategies found in recent literature.

Keywords: WLAN, 802.11, channel scheduling, access point, OCA-ITU

1. INTRODUCTION

The 802.11 based Wireless LAN is one of the robust network strategy to deploy for many distributed network solutions that attracting the phenomenal attention of the industry in 21^{st} century. The constraints such as resource utilization, transmission fairness, channel scheduling of the less infrastructure and wireless based networks are critical and sensitive even in 802.11 WLAN. These networks are equipped with multiple access points and wireless stations. The scenario of communication in WLAN are twofold and they are user to access point and access-point to other network such as internet, the other case is user to access point and access point to other access point or user. These scenarios are often pure wireless or mix of wired and wireless communication. The issues and challenges of these WLAN are compatible to the constraints observed in other wireless networks of type ad hoc and sensor based networks, but the solutions observed in those networks are not adaptable to WLAN [1]. Hence, the research community giving significant attention to device robust and scalable solutions specific to 802.11 based WLANs.

Hence, the context of this manuscript pointed to provide QoS through optimal channel scheduling in pure wireless communication based WLAN strategies. The objective of the scheduling strategy addressed here in this manuscript is to achieve maximal throughput, minimal transmission window loss and idle channel scheduling [2], [3].

2. RELATED WORK

The objective of transmission channel scheduling in the raise of quality is maximizing the throughput and minimizing the transmission loss. Significant contributions about QoS aware data transmission in WLAN found in contemporary literature. Few of these articles [4-8] attempted to balance the TCP-flows and TCP-acknowledgement-flows in order to raise the transmission quality. The constraints of these strategies are assuming transmission channel allocation is always fair enough and the limited to WLAN, which is mix of wired and wireless connectivity.

The other dimension of the solutions found in literature [9-14] are scheduling access points to the associated clients, which is again limited to WLAN infrastructure, where access points are connected to external networks through wired connectivity. Few articles in literature [15-17] are scheduling transmission channels at access point level, but scheduling strategies adapted here in this model are lagging to handle the interference in channel allocation and optimal utilization of the channel idle time-frames. The model devised in [18] is a hybrid approach that aimed to schedule an access point as well as channel scheduling at selected access point.

In order to this, our proposed channel allocation strategy aimed to notify the idle channel that meet the transmission criteria of the window that transmits. If failed then attempts to notify minimal count of channels and segments the window that transmits in to multiple windows such that each window transmitted through one of the selected channel. If still not succeed, then selects channels with considerable intervals between to consequent schedules and segments the window according to the compatibility of the selected channels and fulfil the transmission. The model recommends the transmission windows with varying sizes, which is in order to utilize maximum channel availability that considerably optimal to transmit multimedia data over WLAN.

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3. OPTIMAL CHANNEL ALLOCATION WITHIDLE TIME USAGE (OCA-ITU)

The Optimal Channel Allocation with Idle time usage (OCA-ITU) that proposed in this manuscript is medium access control strategy that functions at WLAN access points.The objective of the OCA-ITU is QoS aware dynamic channel allocation for varying size windows in 802.11 WLANs that enables the usage of idle state of the channels. The idlestate usage can define as usage of the idle time between the schedules in sequence observed for a channel. The OCA-ITU process the optimal channel scheduling in a hierarchy. The proposed channel scheduling for varying size window transmission explored following:

- The window assembler assembles the varying size windows to be transmitted,
- Respective to each window in transmission queue, sends a message frame to access point that informs channel requirements of the respective window. The message frame informs the required channel time, desired bandwidth, the size of the window and its tentative transmission time required to a window to reach access point.
- The window arrival time is the aggregate value of average time required to a window to reach all possible access points, time taken by message frame to reach access point and process-time, which is time taken to analyse the message frame.

Let $\rho_{mf}(w_i)$ beprocess-timetaken to analyse a message frame mf of respective window w_i. Let $a\tau_{mf}(w_i)$ be the arrival time of the message frame mf at access point ap. The tentative transmission time taken by the window w_i to reach access point ap measures as follow:

$$\tau_{w_i} = \frac{\sum_{j=1}^{|AP|} \tau_{w_i}(ap_j)}{|AP|}$$

// average of the arrival tentative arrival times of window w_i observed for all possible access points of count $|AP|$

The tentative arrival time of the window w_i at access point ap measures as follows:

$a\tau_{w_i} = a\tau_{mf}(w_i) + \rho_{mf}(w_i) + \tau_{w_i}$ // the aggregate value of arrival time $a\tau_{mf}(w_i)$ of the message frame mf, process time $\rho_{mf}(w_i)$ and tentative transmission time τ_{w_i} of the window w_i.

According to the information explored from message frame mf of window w_i, the access point schedules channels by using proposed OCA-ITU. The exploration of this model follows in further sections.

3.1. OCA-ITU scheduling strategy

The channel scheduling to the respective window w_i under OCA-ITU is as follows:

The channel selection criterion is channel with desired bandwidth andidles for expected transmission time slot. OCA-ITU initiates window segmenting and channel allocation process under following circumstances:

i. no channel found under this criteria,
ii. window arrival time and channel scheduled time-frame not synced,
iii. multiple channels meet this scheduling criteria or multiple windows expected to be arrived with similar criteria of channel scheduling
iv. channels with desired criteria are fewer than the number of windows expected to be arrived,

If the transmission time of the window w_i is much lesser than the available transmission time-frame of the target channel and if opportunity of channel usage is extremely high, then access point performs the following:

- Schedules an infrequent channel, if available with extremely high transmission time-frame that compared to the desired transmission time-frame for window w_i.
- If failed to trace a channel at this criteria, selects set of infrequent channels with transmission time-frame fewer than the desired time-frame of the window w_i, such that the aggregate of transmission time-frames of the selected channels must be greater than the desired transmission time-frame of the window w_i. Further segments the window w_i multiple windows such that each partition of the window can transmit through one of the channel from the selected set of channels.
- If access point fails to schedule channels under above criterions, then it selects scheduled channels with idle times (intervals between two consequent transmissions), if found then selects channels with idle time-frame that meets the criteria of the transmission time-frame of the window w_i.
- If one channels idle time-frame is not sufficient then segments the window w_i into minimum number of windows such that these new windowscan be transmitted through minimum channels with compatible idle time-frames.

If access point failed to schedule channel(s) under all of the above criterions, then buffers the window and attempts to schedule the channel in frequent intervals, if failed with to schedule the channel with in the life time of the buffered window then drops that window and transmits failure acknowledgement to window assembler.

The strategy of OCA-ITU explored with mathematical notations and algorithm flow in following Sections

3.2. Pseudo representation of scheduling algorithm

OCA: Begin

1. Let mf_i be the message frame representing the window w_i to be transmitted by access point ap_j ,
2. $oc \leftarrow \phi$

//representation of optimal channel initialized to null

3. $oc = selectOC(a\tau_{w_i}, db_{w_i}, etf_{w_i}, |w_i|, \{C\})$

//finding the optimal channel and passing parameters are varying size window arrival time $a\tau_{w_i}$, desired bandwidth db_{w_i} , expected transmission time-frame etf_{w_i} , window size $|w_i|$ and vector of channels available $\{C\}$

4. If ($oc \neq \phi$) Begin //optimal channel found for varying size window w_i
5. channel oc scheduled to varying size window w_i
6. *Exit*
7. End // of condition in line 4
8. Else Begin //of condition in line 4
9. Set $ocl \leftarrow \phi$

// ocl is the set of optimal channels initialized to null, which contains selected optimal channels to transmit multiple segments of window w_i

10. Set $s(w_i) \leftarrow \phi$

// $s(w_i)$ represents the set of window segments formed from the varying size window w_i that initialized with ϕ

11. $< ocl, s(w_i) >= OCL(w_i, \{C\})$

// finding the set of optimal channels to transmit window segments of window w_i

12. If $(ocl \neq \phi \,\&\, s(w_i) \neq \phi)$ Begin
13. For-each $ws \leftarrow s(w_i) \,\&\, oc \leftarrow ocl$ Begin
14. Schedule oc to ws
15. End //of iteration in line 13
16. Exit // since scheduling completed
17. End //of condition in line 12
18. Else Begin
19. $< ocl, s(w_i) >= ITUC(w_i, \{C\})$
20. If $(ocl \neq \phi \,\&\, s(w_i) \neq \phi)$ Begin
21. For each $ws \leftarrow s(w_i) \,\&\, oc \leftarrow ocl$ Begin
22. Schedule oc to ws
23. End //of iteration in line 21
24. Exit // since scheduling completed
25. End // of condition in line 20
26. Varying size window loss inevitable
27. End //of condition in line 18
28. End //of condition in line 8

End // of the function

3.3. Pseudo representation of optimal channel selection algorithm

$selectOC(a\tau_{w_i}, db_{w_i}, etf_{w_i}, |w_i|, \{C\})$ Begin

1. $ec \leftarrow \phi$ // vector of eligible channels is set to ϕ
2. $oc \leftarrow \phi$ // resultant optimal channel set null initially
3. For each $c \leftarrow \{C\}$ begin
4. if $(itf_s(c) + \lambda) > (a\tau_{w_i} - \varphi)$ Begin //channel c is not idle by the arrival time of window, here $itf_s(c)$ is the next idle frame start time of channel c , λ and φ are elapsed time thresholds respective to idle time-frame start time and window arrival time respectively.

a. continue //to next iteration of line 3

5. End // of the condition in line 4
6. Else Begin //of condition in line 4

a. $ec \leftarrow c$ // move channel c to vector ec

7. End //of condition in line 6
8. $ritf_{\min} \leftarrow \infty$ // represents minimal residual idle time-frame set to ∞ initially
9. $rbw_{\min} \leftarrow \infty$ // represents minimal residual bandwidth set to ∞ initially
10. For-each $\{c \exists c \in ec\}$ begin

a. $ritf = ((itf_e(c) - itf_s(c)) - (ttf_{w_i} + \varphi)$

b. $rbw = bw_c - (db_{w_i} + \beta)$ // residual bandwidth observed for channel c to transmit window w_i with desired bandwidth $(db_{w_i} + \beta)$, here β is elapsed threshold of the bandwidth desired.

c. $if\,(0 < ritf < ritf_m) \wedge (0 < rbw < rbw_m)$ begin

i. $ritf_m \leftarrow ritf$

ii. $rbw_m \leftarrow rbw$

iii. $oc \leftarrow c$

d. End // of condition in line a

11. End //of iteration in line 10
12. Return oc
13. End //of the function

3.4. Pseudo representation of window segmenting and optimal multiple channels selection algorithm

1. $OCL(w_i, \{C\})$:Begin
2. $ocl \leftarrow \phi$ //optimal channel list initialized with null
3. $s(w_i) \leftarrow \phi$ //varying size window segment list initialized with null
4. For-each $c \leftarrow \{C\}$ begin
5. if $(itf_s(c) + \lambda) > (a\tau_{w_i} - \varphi)$ Begin //channel c is not idle by the arrival time of window, here $itf_s(c)$ is the next idle frame start time of channel c , λ and φ are elapsed time thresholds respective to idle time-frame start time and window arrival time, respectively.

a. continue //to next iteration of line 4

6. End // of the condition in line 5
7. Else Begin //of condition in line 5

b. $ec \leftarrow c$ // move channel c to vector ec

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8. End //of condition in line 7
9. Sort ec in descending order of $|itf|$

// sorting the eligible channels in descending order of their idle time-frame size.

10. For-each $\{c \exists c \in ec\}$ begin

a. $ocl \leftarrow c$

b. $s(w_i) \leftarrow \breve{w}_i$

// $\breve{w}_i$ is the segment of the window w_i such that

$$[(((itf_e(c) - itf_s(c)) - (ttf_{\breve{w}_i} + \varphi)) > 0] \wedge [(bw_c - (db_{\breve{w}_i} + \beta)) > 0]$$

$$w_i \leftarrow w_i - \breve{w}_i$$

11. $if(w_i \equiv \phi)$ Begin
12. Break // the loop in line 10
13. End //of the condition in line 11
14. Return $< ocl, s(w_i) >$
15. End // of the function

3.5. Pseudo representation of window segmenting and multiple channels with ITU (Idle time usage)algorithm

1. $ITU(w_i, \{C\})$:Begin
2. $ocl \leftarrow \phi$ // indicates optimal channels list for idle time usage, which initialized with null
3. $s(w_i) \leftarrow \phi$ //varying size window segment list bsl initialized with null
4. Sort channels in ascending order of buffer time between window arrival time and channel idle time-frame start time.

   The buffer time of the window w_i under channel c_i measures as

$$b_{w_i}(c_i) = (itf_s(c_i) + \lambda) - (a\tau_{w_i} + \varphi)$$

5. For-each $c \leftarrow \{C\}$ begin

a. $ocl \leftarrow c$

b. $s(w_i) \leftarrow \breve{w}_i$

// $\breve{w}_i$ is the segment of the window w_i such that

$$[(((itf_e(c) - itf_s(c)) - (ttf_{\breve{w}_i} + \varphi)) > 0] \wedge [(bw_c - (db_{\breve{w}_i} + \beta)) > 0]$$

$$w_i \leftarrow w_i - \breve{w}_i$$

6. $if(w_i \equiv \phi)$ Begin
7. Break // the loop in line 5
8. End //of the condition in line 6
9. Return $< ocl, s(w_i) >$
10. End //of the function

In order to perform the channel scheduling, OCA-ITU initiates to track possible optimal channel (see sec 3.3).If failed then attempts to segment the window in to multiple windows such that minimum number of idle channels can be scheduled to transmit the all window segments (see sec 3.4), if still not succeed to meet this criteria then aims to utilize the channel intervals between two consequent schedules of channels in use (see sec 3.5). Here the process of segmenting the window is on demand; hence, the segmentation process claims minimal overhead. If OCA-ITU failed to schedule the channel under any of the adapted criterions then it drops the window and the sends failure acknowledgement to the window assembler.

4. EXPERIMENTAL SETUP AND EMPIRICAL ANALYSIS

The performance of OCA-ITU assessed through simulation study that compared to other benchmarking models hybrid scheduling scheme (HSS) [18] and scheduling and association algorithm (SAA) [17]. The 802.11based WLAN under ESS network topology simulated by using NS2 and parameters used in simulation environment is as follows (see Table-1).

Table-1. Parameters used in 802.11 WLAN simulation.

Network topology	ESS
No of nodes as users	50
No of access points	8
Channels per access point	16
The range of Varying size window generation threshold	32KB to 512KB
Range of bandwidth	512MB to 1536MB
elapsed threshold values used	0.05% of actual
The Simulation time	12 minutes

Divergent varying size windows formed from the data of the size between 10GB to 25GB. The window varies in size in the range of 32kb to 512kb. The proposed OCA-ITU is compared to HSS [18] and SAA [17] found in contemporary literature. Performance of the OCA-UTI is assessed by QoS metrics called window loss against transmission window load (see Figure-1), throughput achieved against transmission window load (see Figure-2),

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and process overhead observed against transmission window load (see Figure-3).

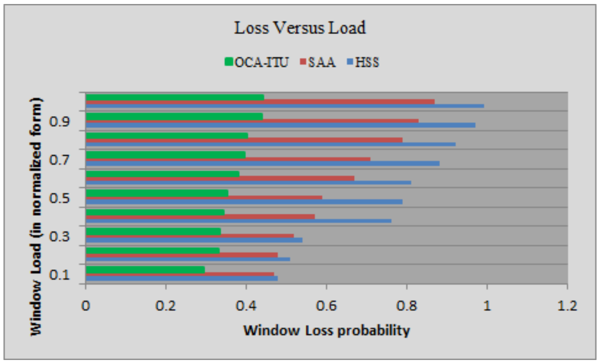

Figure-1. Varying size window load versus varying size window loss.

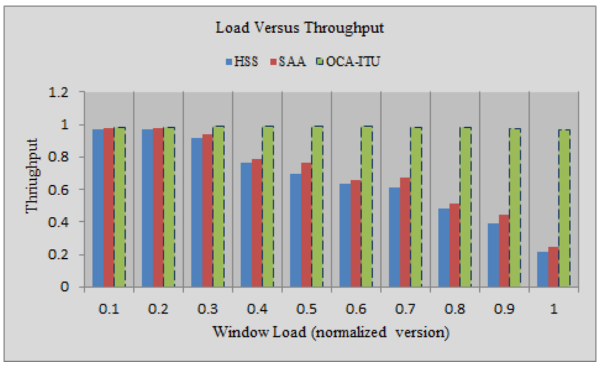

Figure-2. Varying size window load versus throughput.

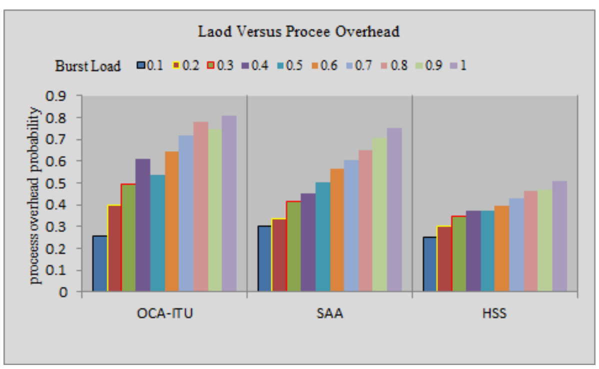

Figure-3. Process overhead versus varying size window load.

The ratio of window loss against the window load is evinced in Figure-1.The window load is normalized to the value between 0 and 1, which is actually the number of windows per second. The experimental study indicating that the OCA-ITU is significantly defused the window loss that compared to other two models (see Figure-1). Hence the high throughput observed for OCA-ITU (see Figure-2). The multiple channel selection and window segmentation process of the proposed OCA-ITU leads minor process overhead that compared to other two models (see Figure-3).This can be tolerable in order to achieve maximum throughput with minimal window loss.

5. CONCLUSIONS

Optimal Channel Allocation with Idle Time Usage (OCA-ITU) is a channel scheduling protocol for 802.11 WLANs devised here in this manuscript. The objective of the OCA-ITUis maximizing the optimal channel allocation in the context of better throughput and minimal window transmission loss. The OCA-ITU scheduling is a hierarchical approach that allocates optimal idle channel, optimal multiple idle channels or optimal multiple channels with considerable transmission intervals, which are in respective order of the hierarchy. The experimental study evincing the scalability and robustness to achieve maximum throughput and minimal transmission window loss over other contemporary models HSS and SAA. This protocol can extend further to minimize the process overhead observed under second stage that attempts segment and schedule the varying size window. Other dimension of the future work can be the optimal channels allocation through suspend and reschedule the allotted channels to achieve stable throughput and minimal window loss for multimedia transmissions in 802.11 WLAN.

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