Wireless LAN's (WLANs)

WLAN Standards

The field of WLAN is expanding rapidly as a result of advancement in

- **Digital communication**
- **Portable Computers**
- **Semiconductor Technology**

With such increasing demand of WLAN two standards are defined

1.IEEE 802.11

2.HIPERLAN

- IEEE 802.11 is a CSMA/CA protocol
- IEEE 802.11 committee , developed standard in 2.4GHz ISM band
- This medium access protocol supports DCF, and PCF functions and association ,encryption/decryption procedure and power management procedure.

HIPERLAN

HIPELAN work on two bands :

5.15 –5.30 GHz, 17.1-17.2 GHz

Function of HIPERLAN to Provide

- High data Rate (up to 54 Mbps)
- Multihop Routing
- Time Bounded Services
- Power Saving Features

Challenges in WLAN

Frequency Allocation—

In WLAN area all users operate on a common frequency band, its difficult to allocate the band due to available radio spectrum

Interference and Reliability—

- Interference due to simultaneous transmission from two or more STAs.
- Due to Hidden station Problem, STA unable to heard others STA transmission.
- Also caused by Multipath fading ,which result due to amplitude and phase fluctuations at the receiver.

Human Safety—

Research is ongoing to determine RF effect on human illness.

N/w should be designed to minimize the power transmitted by device.

Challenges Contd.

Security—In wired medium transmission is physically secured and proper control of network.WLAN transmission medium is open , data privacy is done by encryption. Encryption causes increased cost and performance.

Throughput—Due to physical limitation and available bandwidth data rates up to 1-20 Mbps is possible.

To increase throughput Mac protocols are optimized and also on the other layers.

Power Consumption—

Today power consumption of Wireless device is biggest concern. Wireless devices are battery powered and portable

Most of the power is consumed in sensing the channel .

Energy efficient techniques are used to increase sleep time and to avoid sleep to awake transitions.

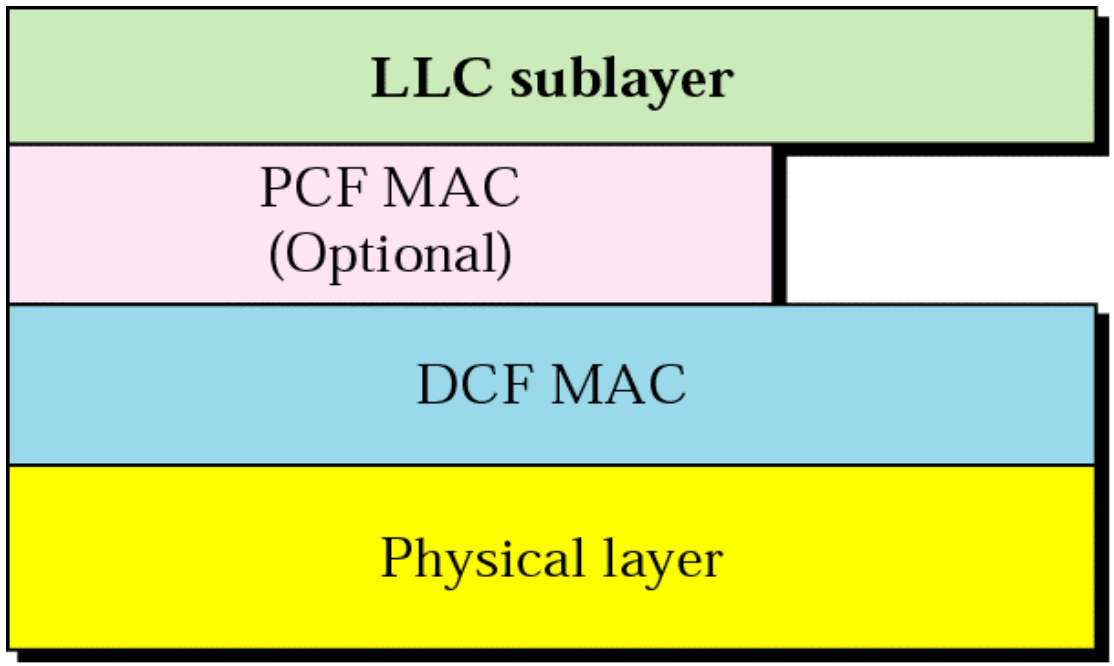
Wireless Network Overview

- APs (access points) and stations
- BSS (Basic service set)
- DS (Distribution system) and ESS (Extended Service Set)
- Ad-hoc networks

BSS is a group of stations that are under direct control of a single coordination function (PCF or DCF).

The geographical area covered by the BSS is known as Basic Service Area (BSA).

802.11 MAC protocol



- DCF – distributed coordination function
  - does not use any kind of central control
- PCF – point coordination function
  - uses base station to control all activity in the cell

MAC Control Functions

1. **Distributed Coordinated Function**
2. **Point Coordination function**

DCF

- DCF is the fundamental access method of IEEE 802.11 known as CSMA/CA
- All station follow a common distribution function.
- In DCF all station transfers the frames through contention and share a common channel.
- DCF used in time insensitive service like Asynchronous data transfer.

PCF

Point coordination Function

- IEEE 802.11 MAC also incorporate optimal access method called PCF.
- Only useful in infrastructure networks
- Data transfers takes place through an AP.
- AP performs the role of Polling Master.
- PCF is useful for time sensitive service like Packetized voice and video.

Types of Network

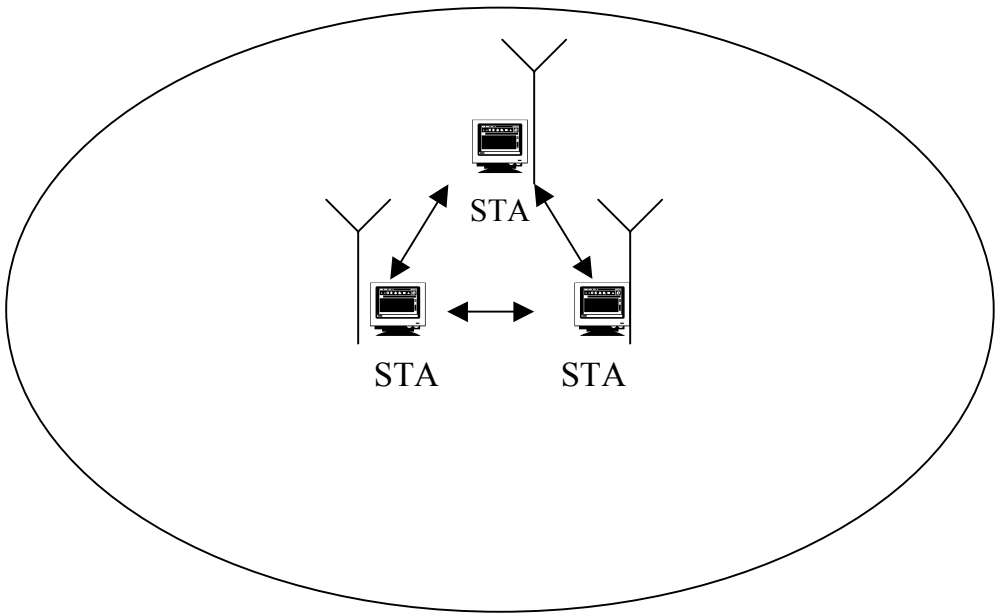
Ad-Hoc Networks characteristics

- Temporary set of stations
- No AP
- No relay function (direct connection)
- Simple setup

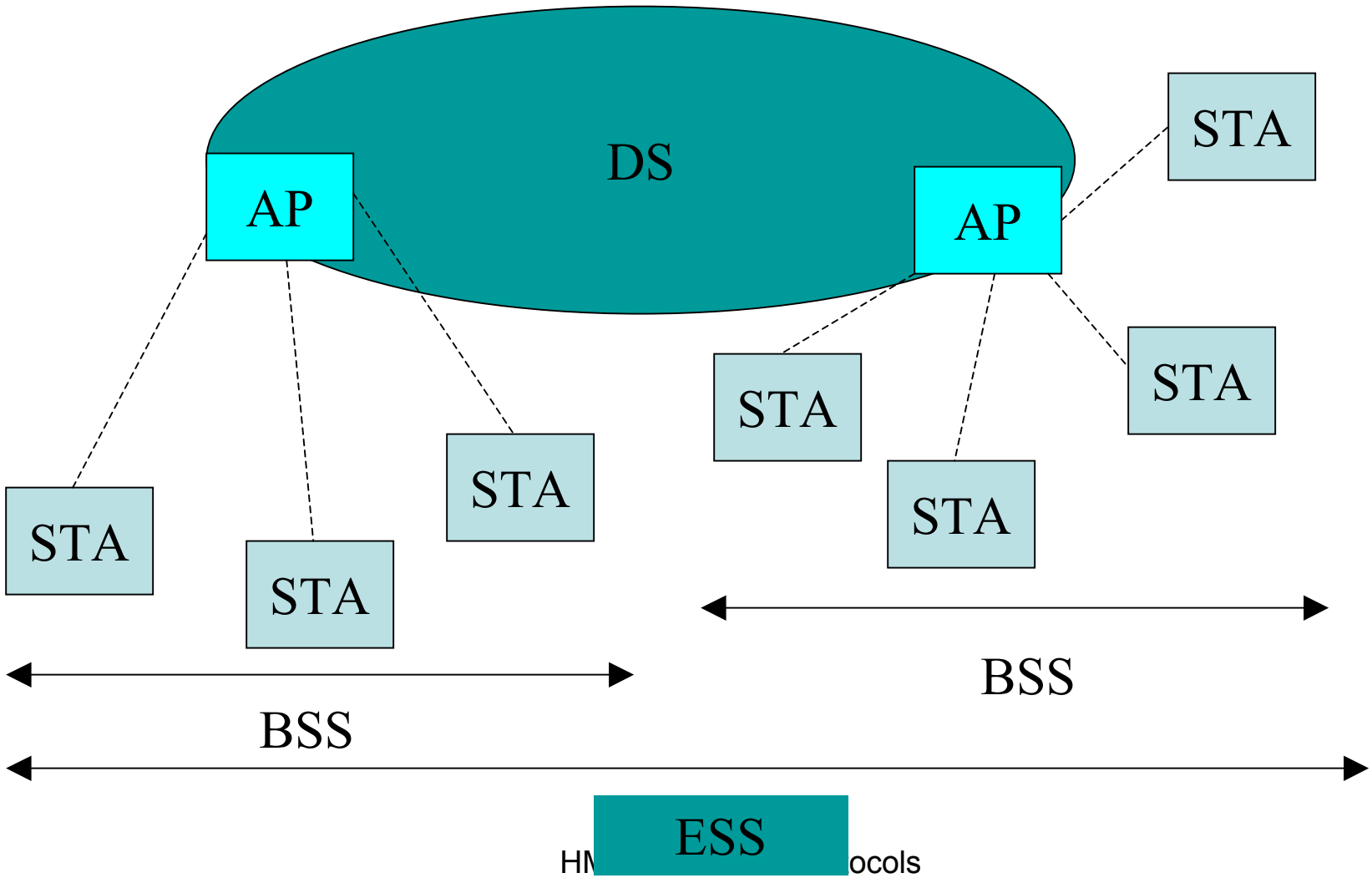
Infrastructure Networks

- Established using APs
- An AP support range extension between multiple BSS ,helps in forming ESS
- ESS consist of multiple BSS and integrated using a common distribution system.

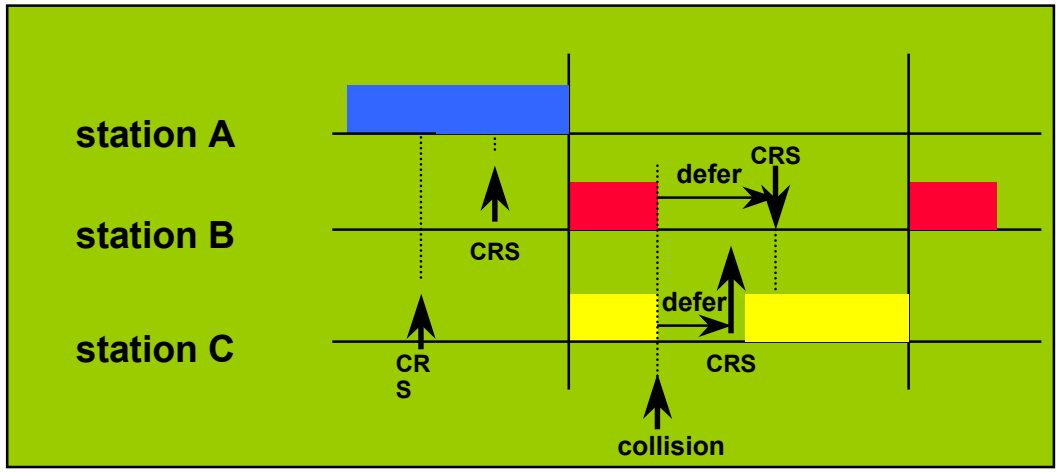
Ad-hoc Network



WLAN 802.11 network

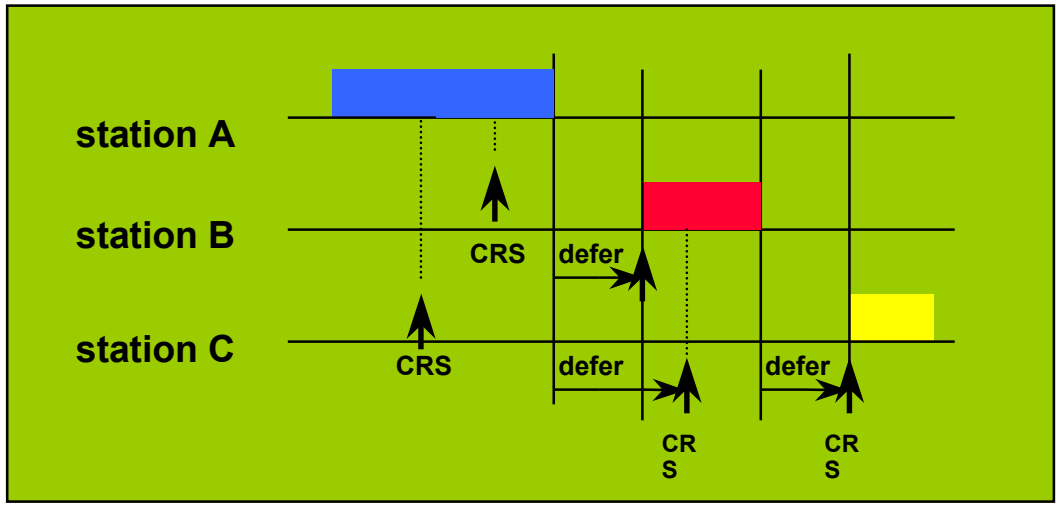


Accessing the medium CSMA/CD



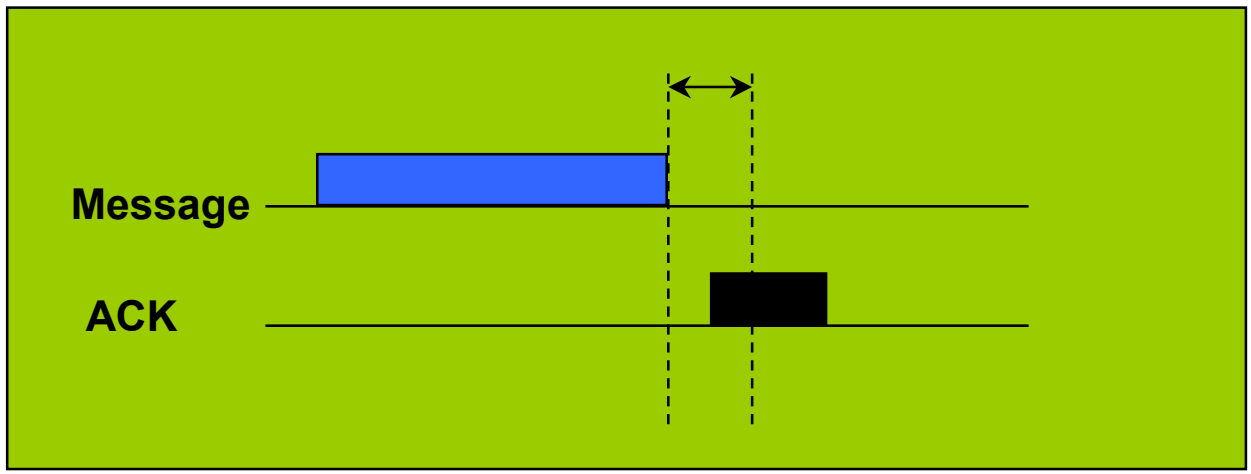
- Adapters that can detect collisions (e.g. Ethernet adapters)
  - Carrier Sensing: listen to the media to determine if it is free
  - Initiate transmission as soon as carrier drops
  - When collision is detected station defers
  - When defer timer expires: repeat carrier sensing and start transmission

Accessing the medium CSMA/CA



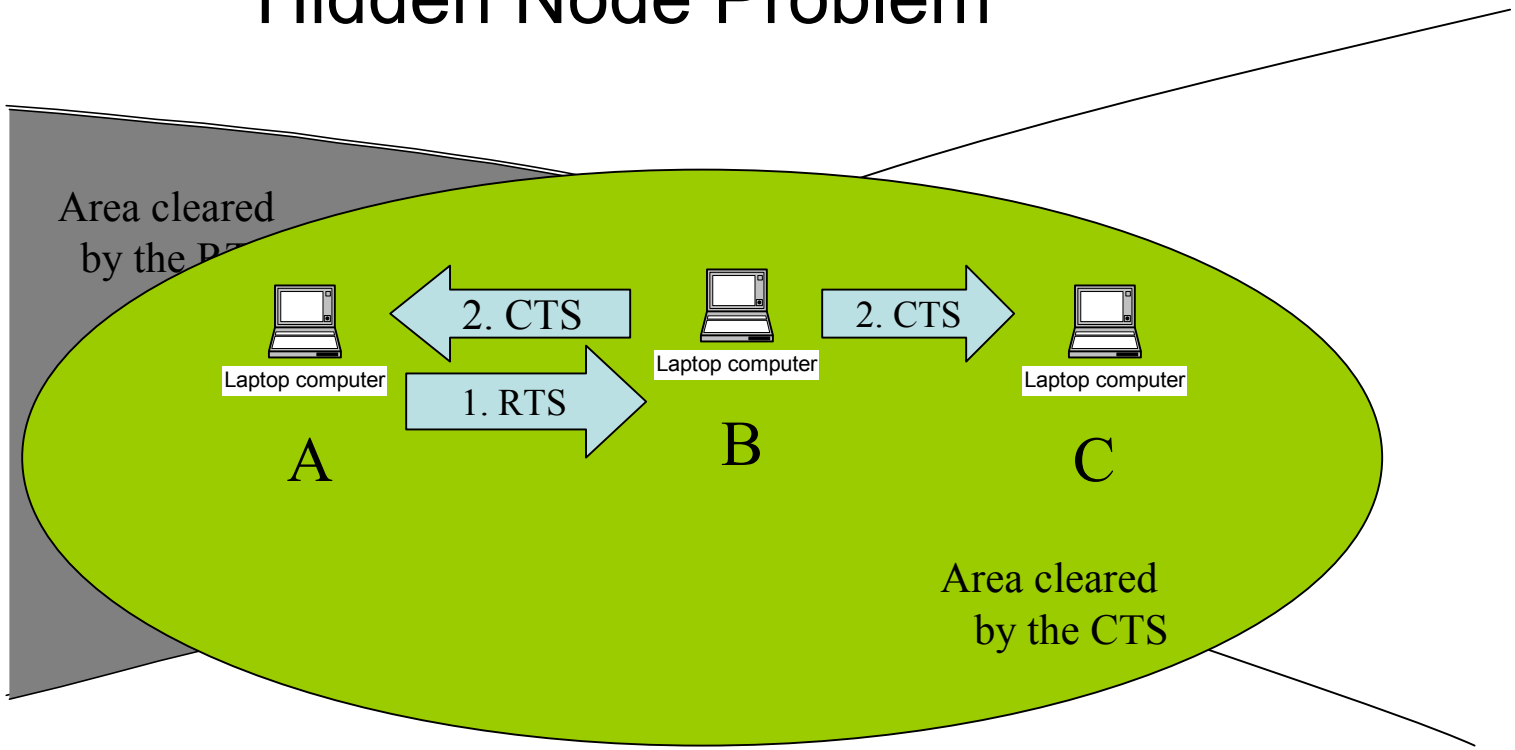
- Wireless LAN adapters cannot detect collisions:
  - Carrier Sensing - listen to the media to determine if it is free
  - Collision Avoidance - minimize chance for collision by starting (random) back-off timer, when medium is sensed free, and prior to transmission

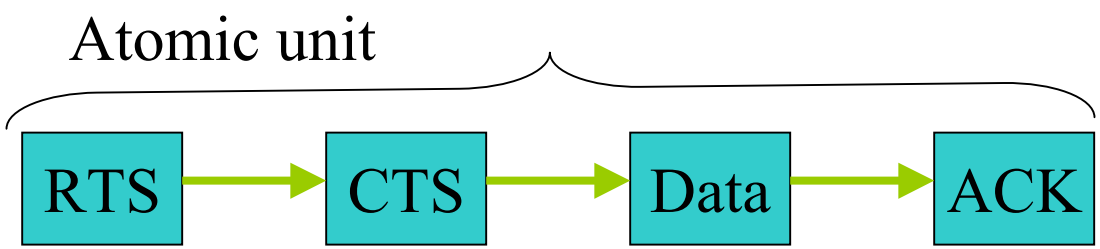
CSMA/CA with MAC - level Acknowledgment



- Collisions still can occur (interference; incapability of sensing other carrier)
  - IEEE 802.11 defines “low-level” ACK protocol
  - Provides faster error recovery
  - Makes presence of high level error recovery less critical

Hidden Node Problem





Solving the Hidden Node problem

- Request To Send (RTS):
  - Source announcing its transmition.
  - Source neighborhood stop transmitting
- Clear To Send (CTS):
  - Destination received the RTS and announce the source to send the data.
  - The destination neighborhood stop transmitting.

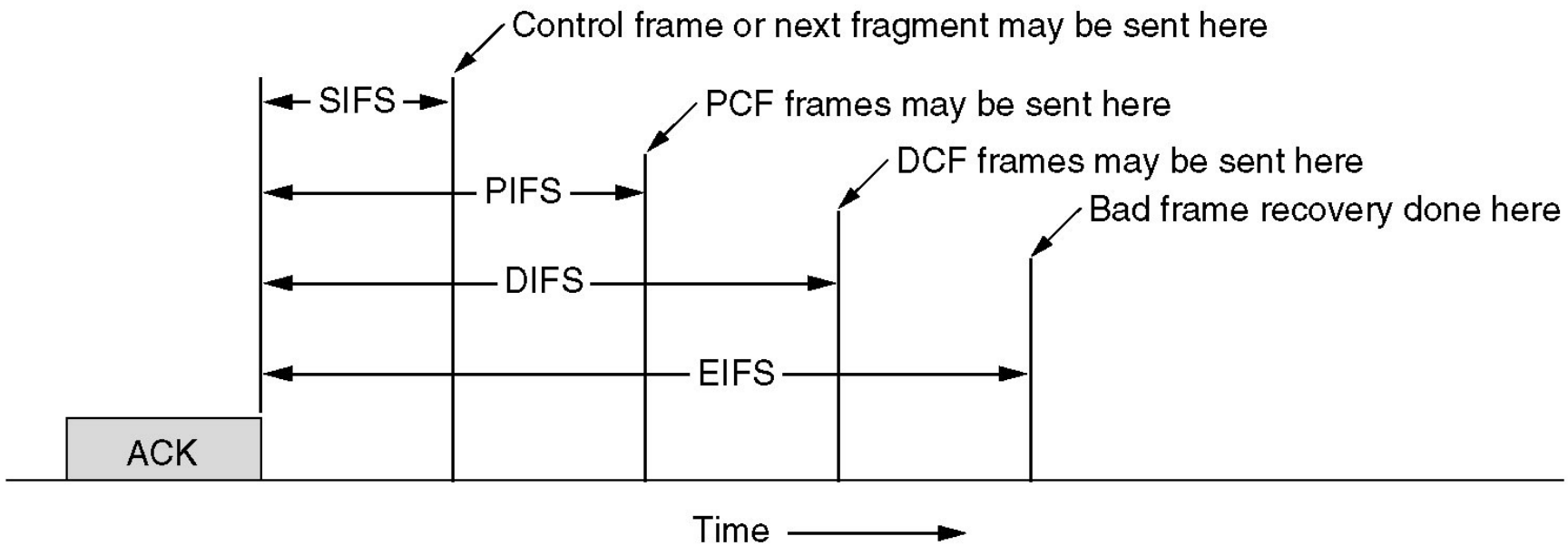
Inter Frame Space (IFS)

There are four different IFS are defined to provide priority levels for access to the wireless media

- SIFS short inter frame space
- PIFS PCF IFS
- DIFS DCF IFS
- EIFS Extended IFS

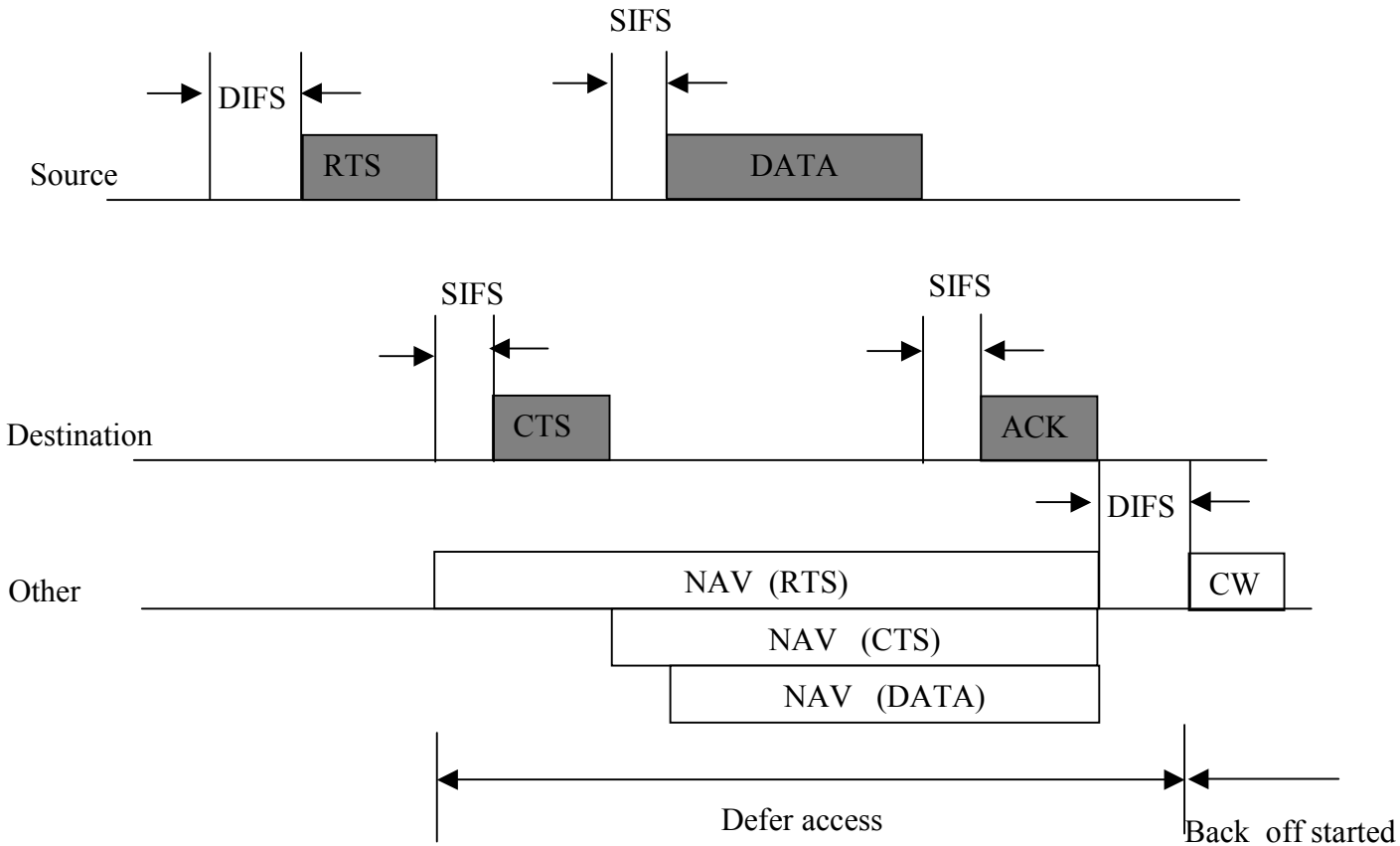
- SIFS is used for *ACK* and *CTS* frame and second or subsequent MPDU of a fragment burst.
- PIFS used for STAs operating under *PCF* procedure.
- DIFS used for STAs operating under DCF to transmit *data frames* and *management frames*.
- EIFS used by the DCF whenever PHY has indicated to the MAC that a frame has errors .

Wireless LAN Protocol: CSMA/CA

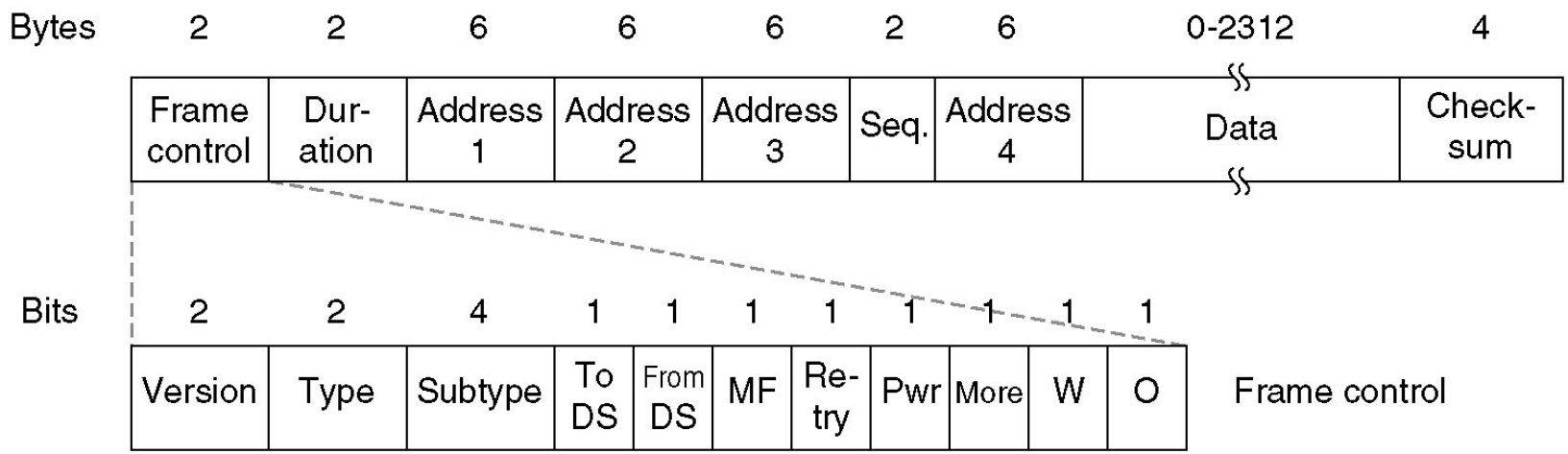


Interframe spacing in 802.11.

DCF Access Procedure



The 802.11 Frame Structure



The 802.11 data frame.

IBSS Power Saving Mechanism

Power consumption is an important issue in WLAN

Wireless devices are generally portable devices where energy is important.

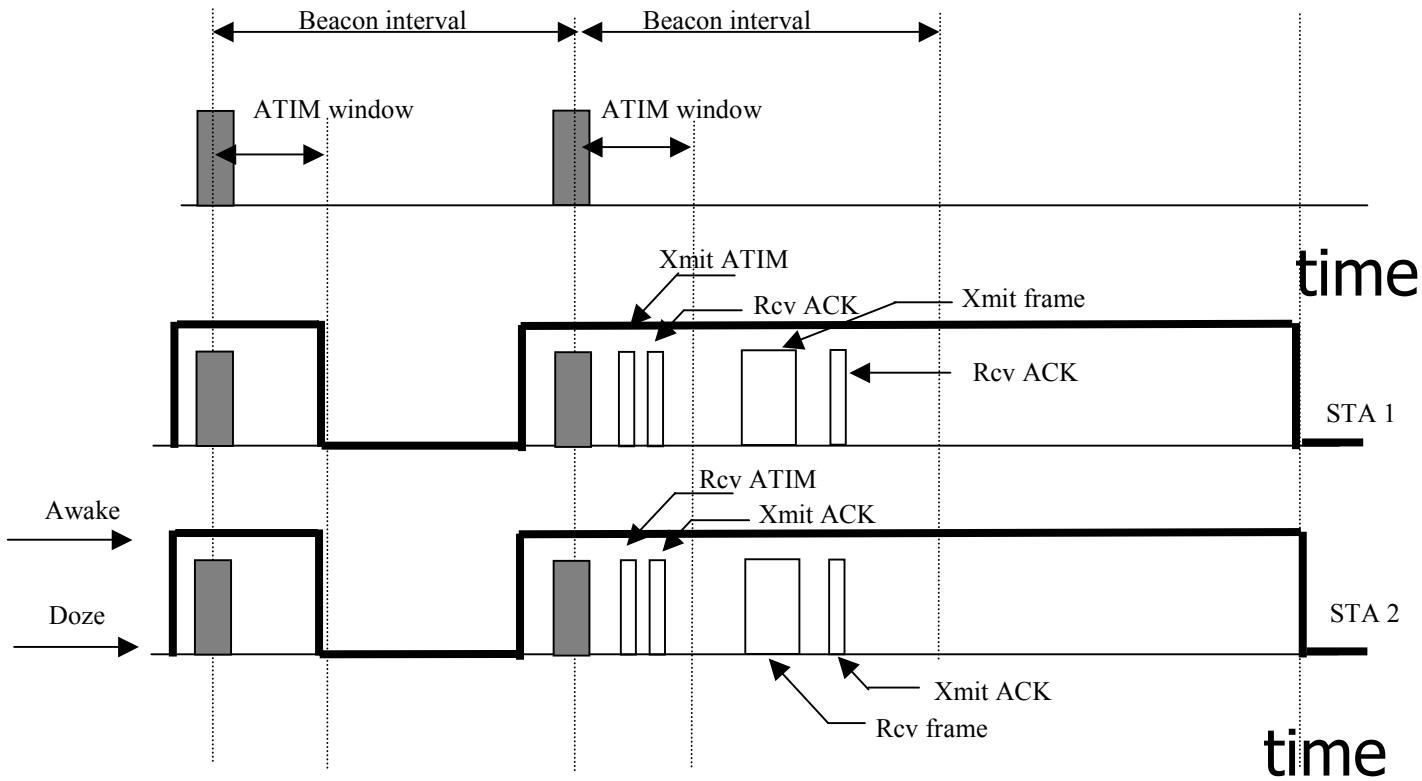
Most of the power consume in sensing the channel .

To address the issue of Power IEEE 802.11b wireless extension provide Power save Mechanisms

Key points are in this procedure

- In this all stations awake for a certain period called ATIM window.
- ALL MPDUs transmitted to PS stations are first announce in ATIM window.
- If PS STAs has announcement by other STAs for announced data it need to remain awake for next ATIM window period ,otherwise PS STAs go to sleep.

Timing Diagram of IBSS Power Save Procedures



Power Saving issues in WLANs

- 1 Mbps WLAN card consumes *12 times* more power than standard Ethernet card
- PS can be achieved by optimized
  - Use of PHY services
  - MAC protocol
  - System Design
- Higher Bit rates consume more power (equalization to deal with ISI)
- About 90% power is used in Carrier sensing (in standard protocol)

At MAC layer

- Excessively long headers consume more power
  - Header compression
  - Packet type splitting
    - Low bit rate for control packets
    - High Bit rate for data packets
  - Put NIC in awake/doze mode
    - STA should be able to receive packets in PS scheme
    - STA should be able to send packets in PS scheme

At system level

- Power hungry hardware at APs (Asymmetric Design)
- All data transfer through PS (MT-PS-MT) will waste bandwidth (two-hop data transfer)
- Issues are
  - Delay
  - Throughput
  - QoS

contd

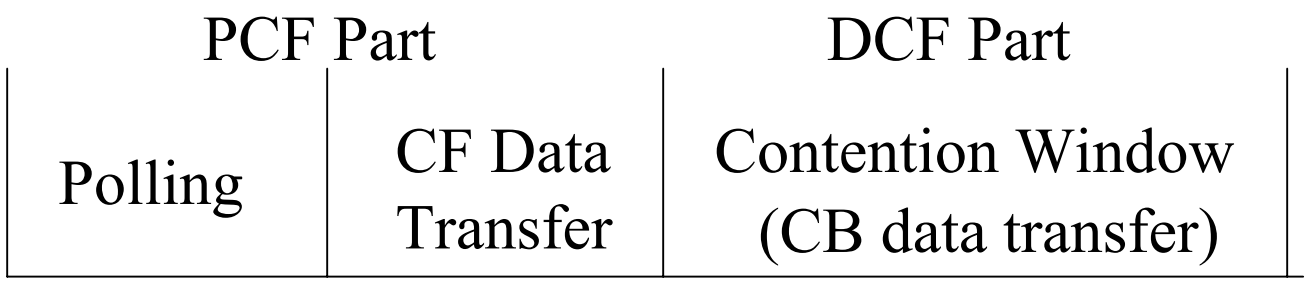
- ***Inactivity Threshold Period*** (ITP)--Power Consumption is also reduced to make the system sleep if there is no activity ,in a certain time called ITP .Lower value of ITP are generally preferred for WLAN cards.

- ***DPSM--*****They uses variable ATIM window size.**
- **Longer dozing time compared to 802.11 PSM**
- **need not remain awake for full beacon interval**

- Span- A power save technique for multihop wireless network.
- It a randomized algorithm where STAs decide based on local decision whether to sleep or to join the network
- **Key features of Span**:
- No advertisement for packets between coordinators.
- Individually advertise each broadcast message
- New Advertise traffic window.

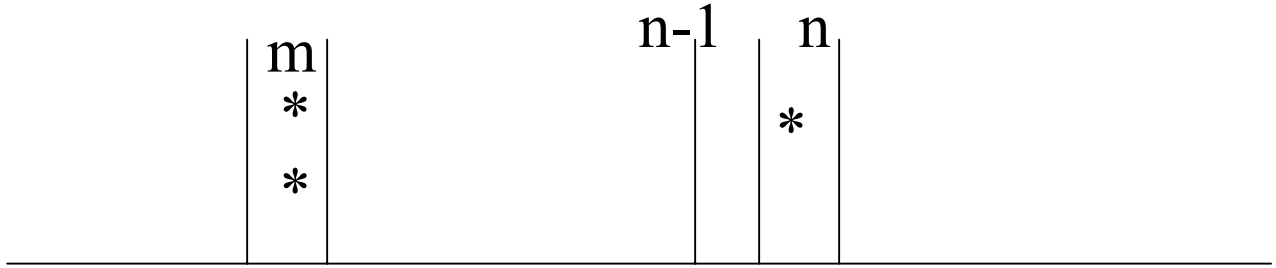
PS in 802.11

- PCF is a scheduler
  - Supports time bound (synchronous service)
  - Uses contention-free (CF) interval on the top of DCF Contention Based interval



PS in 802.11….(contd)

- MAC uses CSMA/CA
- STA selects a number ‘n’ from an uniformly distributed window
- STA waits until(n-1) slots (slot is 9 micro second in 802.11)



* * Previous Cycle value where Channel was captured

* Transmission Allowed here

PS in 802.11….(contd)

- No other STA transmits during n-1 slots
- If any other STA transmits (having lesser ‘n’ value), it defers transmission until packet exchanges
- In the next cycle counter is reduced from the ‘previous cycles’ value (priority is built in)
- Packet exchange deferred time through NAV (including RTS/CTS exchanges)
- PCF has higher access priority (PIFS lesser than DIFS)

Basic Technical Issues

- Awake/Sleep/ procedure can be easily implemented in APs as compared to MTs
  - TSF (Time synchronization Function) is needed
    - Implemented using Beacon Frame (contains a time stamp)
    - Data Packet (DP) transmitted in beacon interval
  - DPs indicate through Traffic Indication Map (TIM)
  - A station is awake in beacon interval if TIM indicates packet for it otherwise sleeps

BF1 – DP1 DP2 BF2 DP3 BF3 DP4 DP5…….

- DPs indicated through Traffic Indication Map (TIM)
- A STA is awake in the *whole* beacon interval if TIM indicates packet for it, otherwise sleeps.

Performance Limitations of IBSS Power Save Mechanisms

High power consumption

Once Frames to transmit are announced in the ATIM window STA transmit only after ATIM window after contending for its slot using normal DCF access procedures.

Station need to remain awake for full beacon interval even if he gets the announced frame,this leads to high power consumption.

Lower Throughput

It is because it follows the normal DCF access procedure used for contending the channel.Due to contention random backoff procedure is called among STAs. Results in loss of data .

States Description

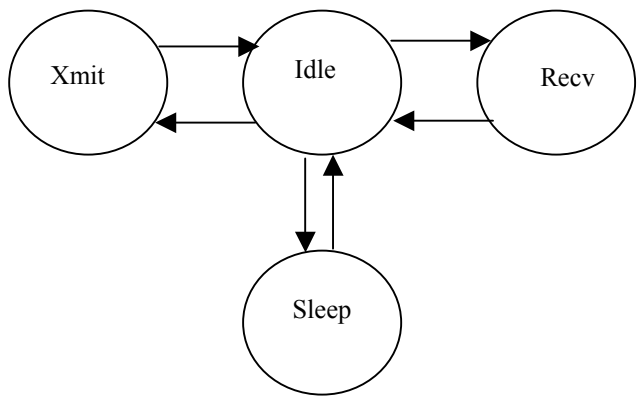
There are four States of a Wireless Radio

1.Transmit

2.Receive

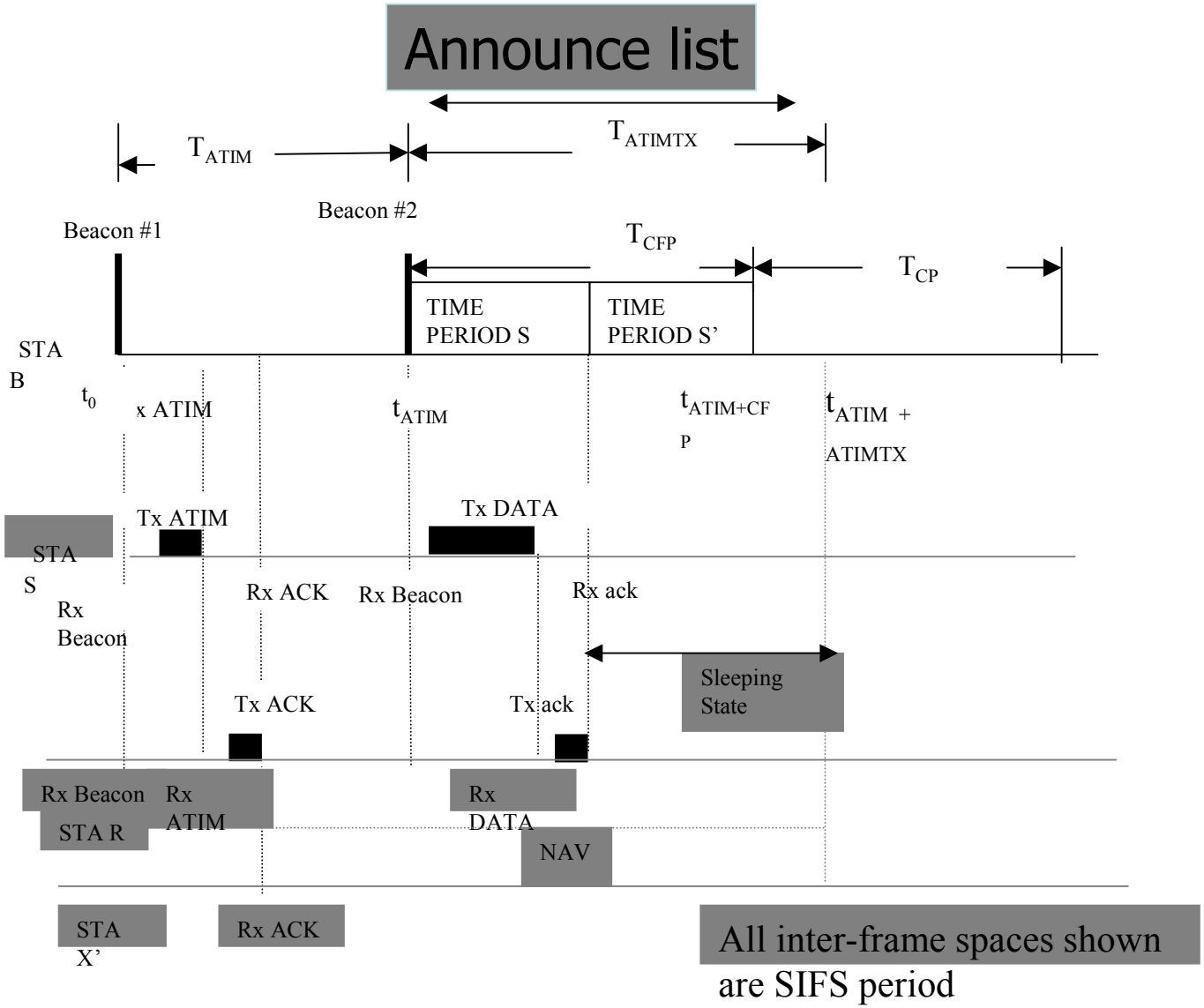
3.Idle

4. Sleep, Most of the power consumed in listening the channel that is in the idle state.



CFPSM

- Contention-free data frames transmission after an initial channel reservation period ***without any centralized control***
- Station making this schedule is called beacon transmitter
- List containing schedule is called Announce List [AL]
- CFPSM mechanisms improves the throughput and reduces the power consumption



Contention-free transfer of announced frames to PS stations

As seen from the CFPSM timing diagram Beacon transmitter hears all ATIM-Ack exchange and announce the list after ATIM window ends.

STAs listen their schedule and go to sleep both before and after the data receipt.

STAs as seen in timing diagram need not awake for full beacon interval.

Features of CFPSM

- **Use of Existing Hardware**-CFPSM protocol makes only software enhancement , it can work by minimal changes in existing WLAN card.
- **Cumulative ATIM Frames**-- We do not transmit separate ATIM for each data transmission to a receiver
- **Distributed control**--current beacon transmitter handles the announce list, in each beacon interval this is random .so the procedure is Distributed in the WLAN.
- **Reducing State transition**--we reduce sleep to awake transition.

Contd

- **Throughput Improved--** data transfer after ATIM window is totally contention free due to which throughput of system increases.

- **Power Consumption**-- STAs need not to awake for full beacon interval, they awake just before the Precise time instants and go to sleep when intended frames are through.

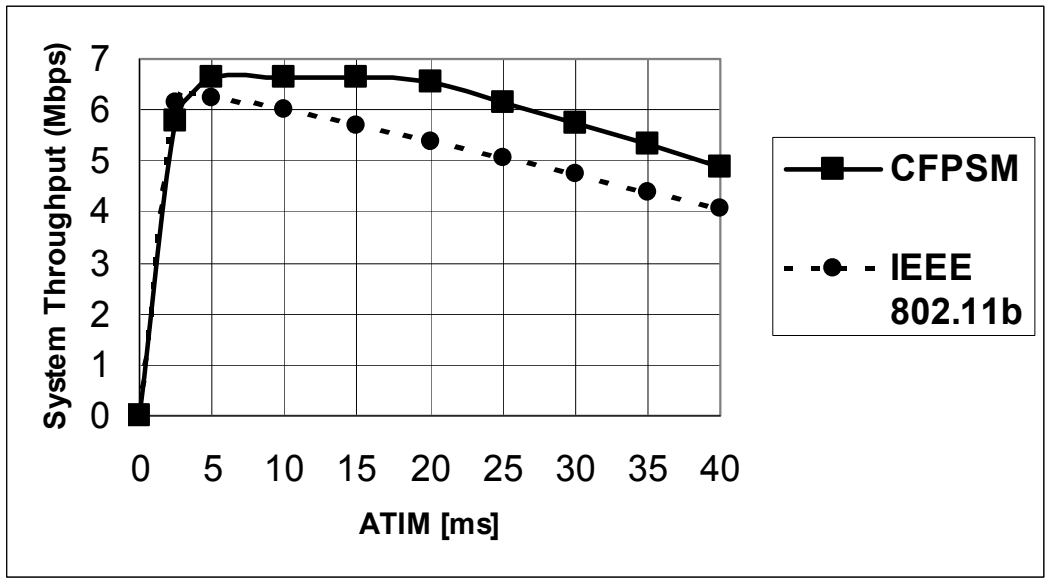
Simulation Tool

- We used the NS-2 version developed by University of California.
- NS-2 supports wireless and mobile networking and other IEEE standards also.
- In NS-2 we change the MAC layer code and make the script in TCL for different configuring parameters
- Simulation tool is available at http://www.isi.edu/nsnam
- Mobility extension is available at http://www.monarch.cs.rice.edu

Performance Parameters

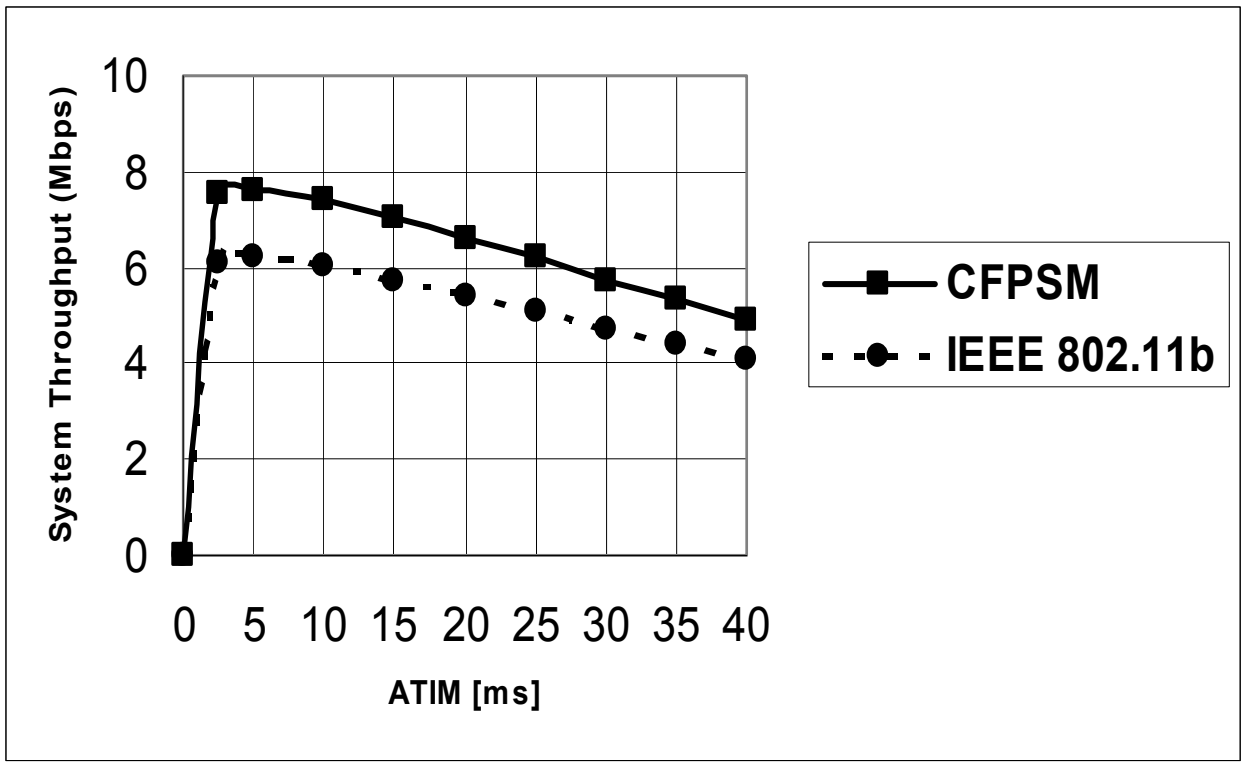
- We measure ***System Throughput*** for Unicast and Broadcast mode .
- We measure ***Average power consumption per node*** in Unicast and Broadcast mode.
- We measure ***Saturation Throughput*** by varying the node density.
- We measure ***SystemThroughput/Energy*** for comparison our performance with Vaidya paper.

System Throughput at 60% load

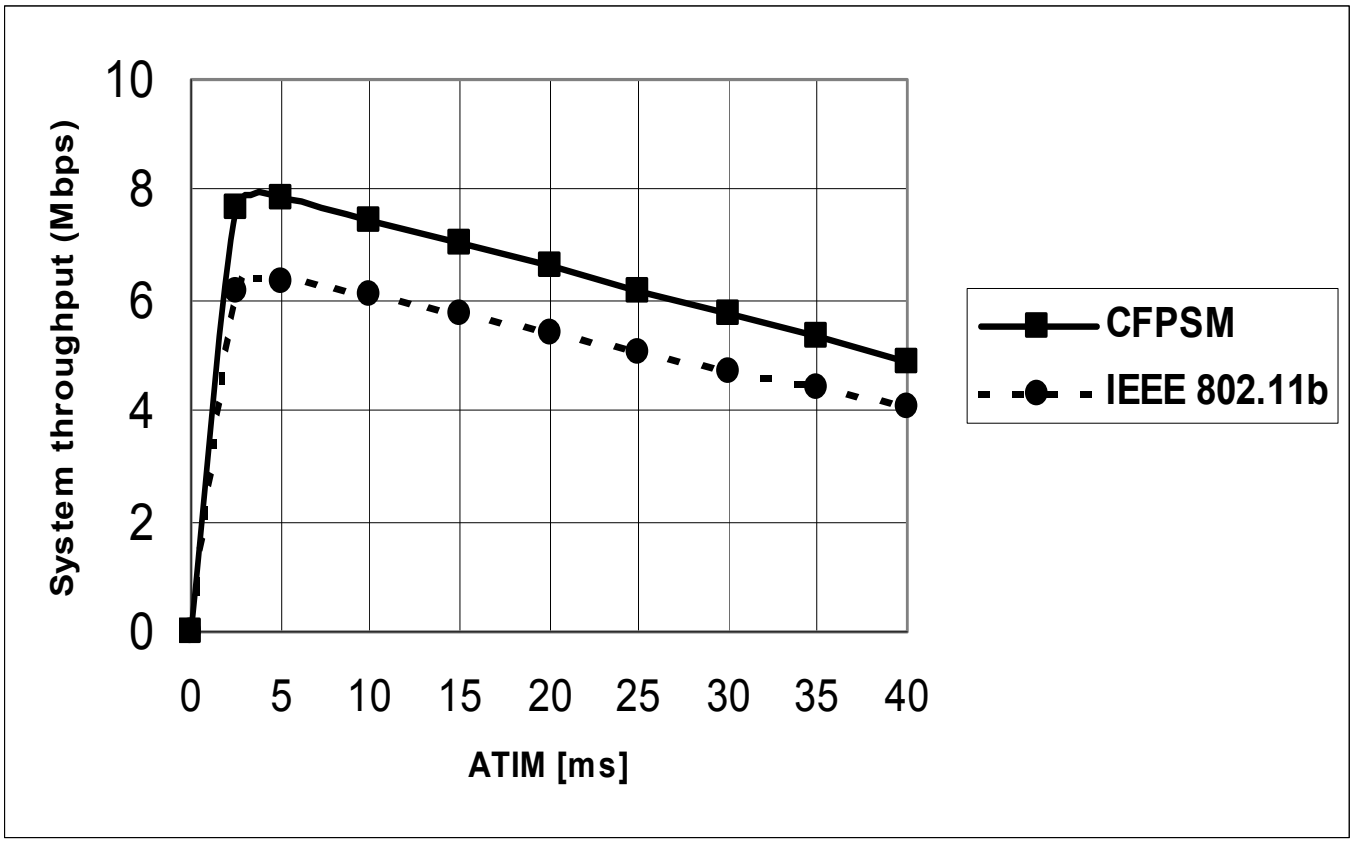


System Throughput at 60% load of 11Mbps using unicast mod

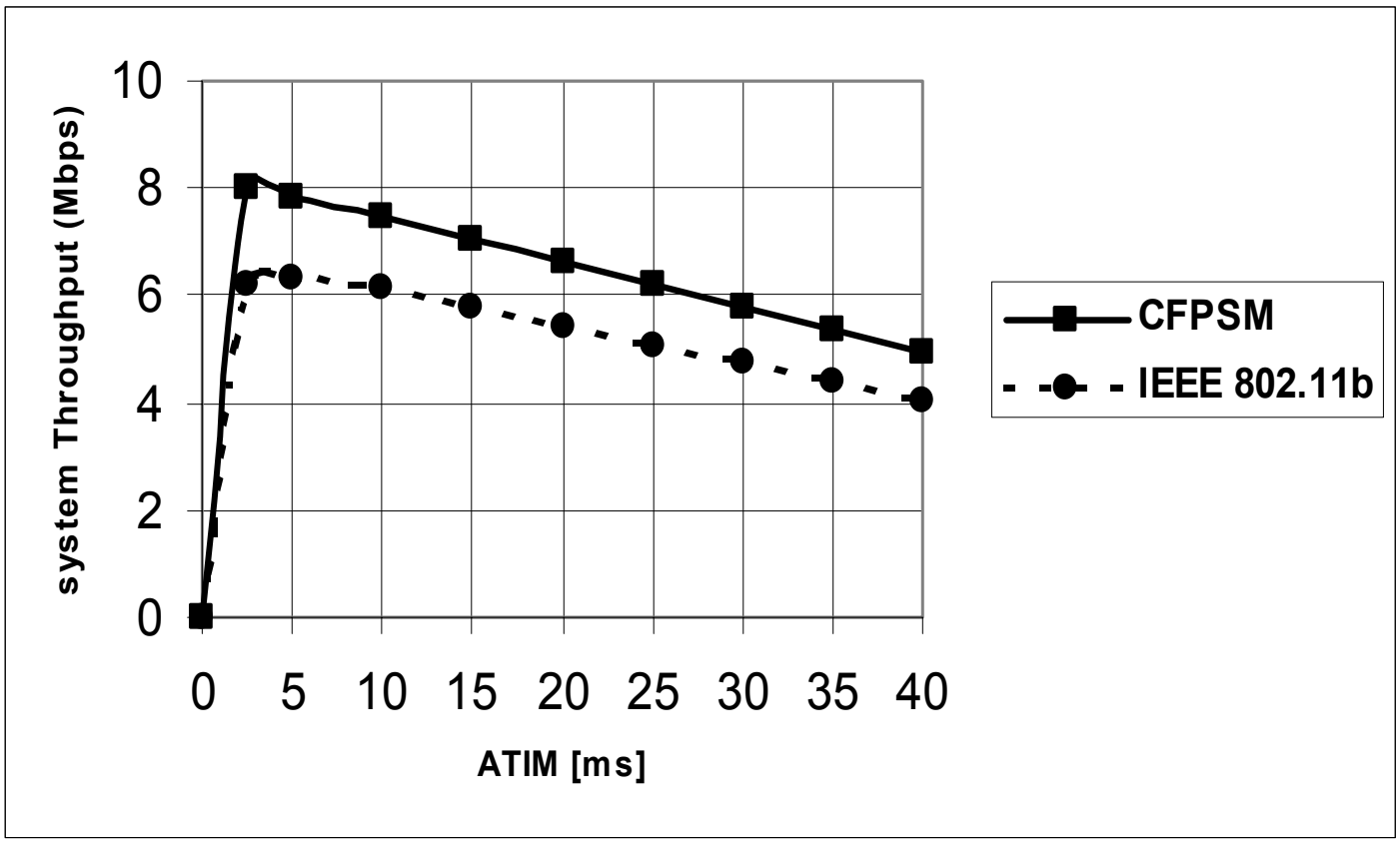
System Throughput at 70% load



System Throughput at 80% load



System Throughput at 90% load



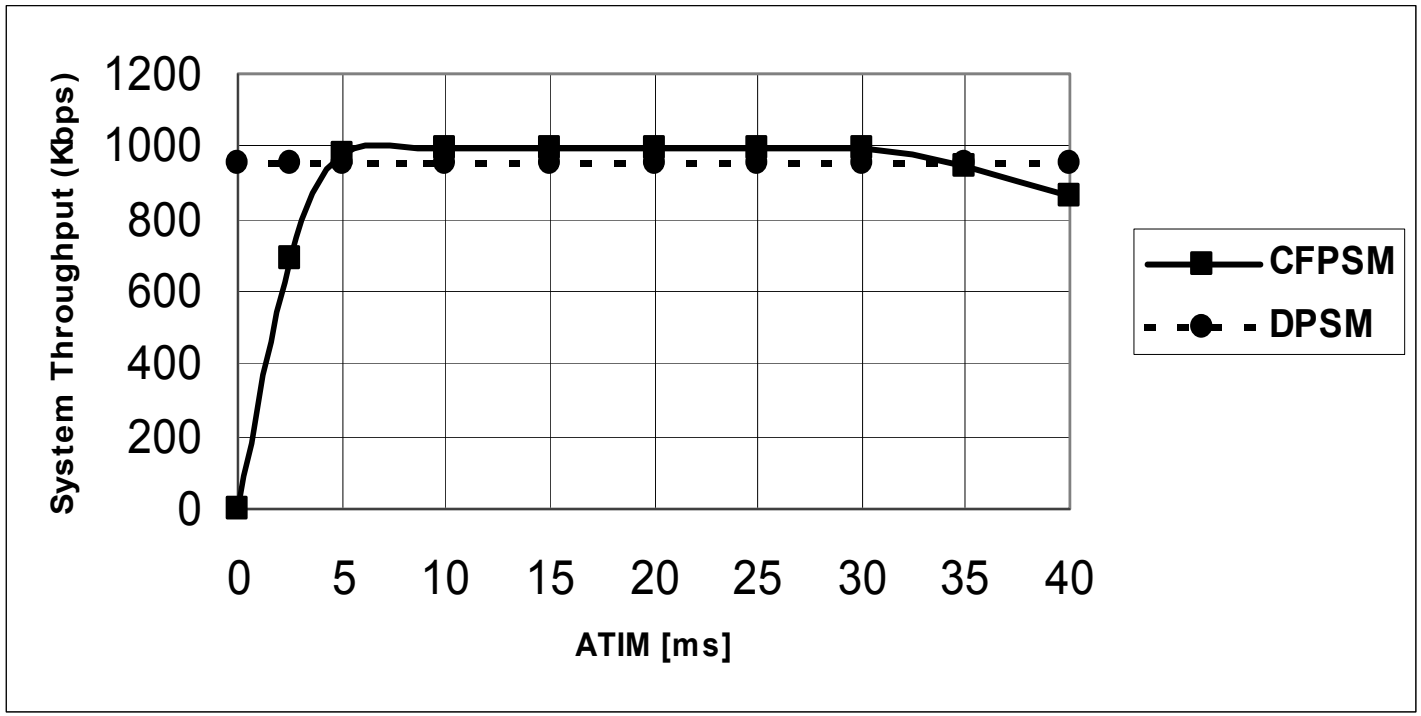
Comparison of the System Throughput with the 802.11 PSM

- As see form the result system throughput of CFPSM is 25%
- better than the 802.11b PSM .
- At 90% load CFPSM has 8Mbps while 802.11 b PSM has on 6.18 Mbps at 2.5 ms.
- At higher load CFPSM performs better than the 802.11b.
- At all values of ATIM window size we got better result than 802.111b
- At other loads we get 18% to 25% improvement in throughput

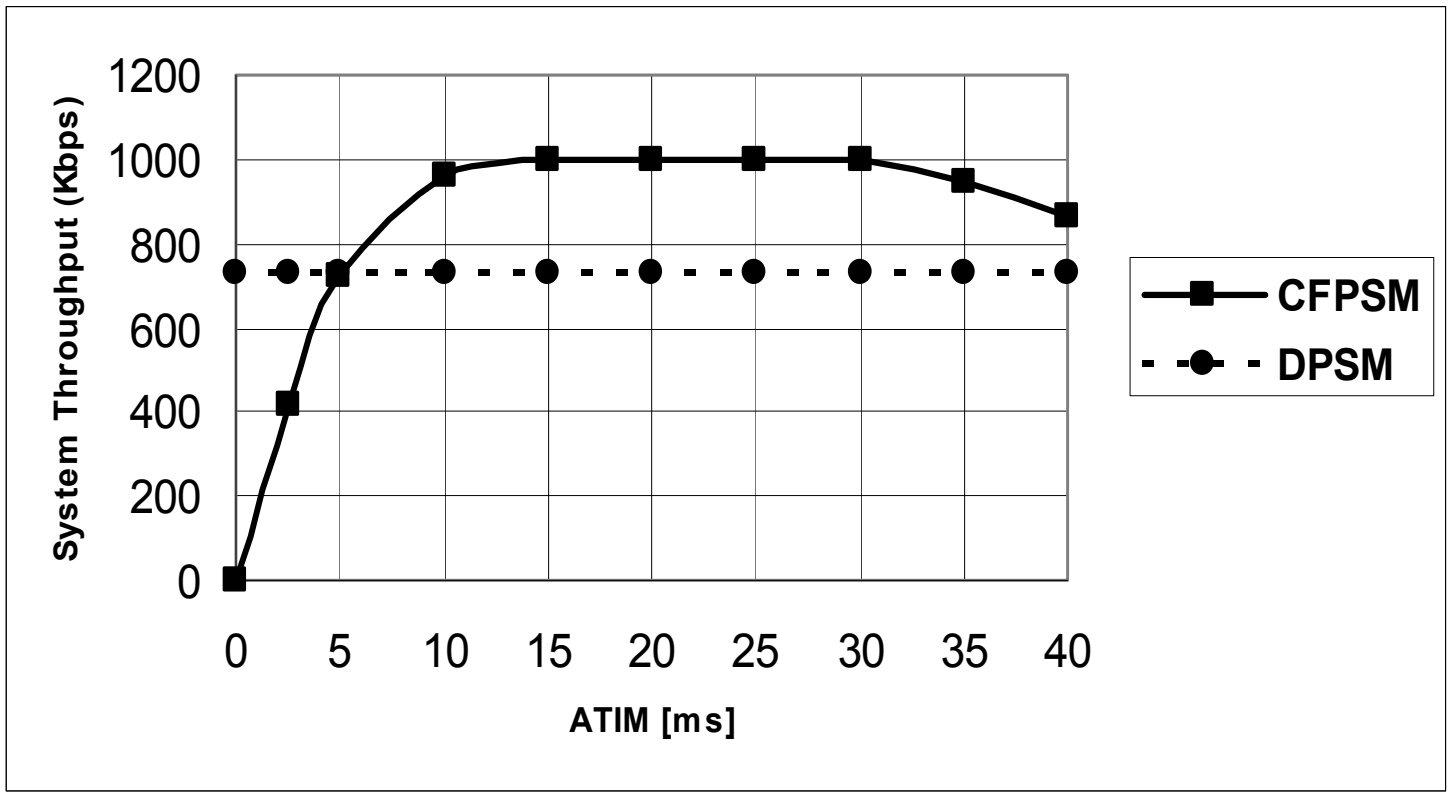
Contd

- As ATIM value is less ATIM-ACK exchange are less result in less System throughput
- As ATIM window is more , ATIM-ACK exchanges are more b the there is less time for actual data transfer.
- So in both cases , CFPSM and 802.11PSM System Throughp decrease as ATIM window is increased.
- So there is a optimum value of ATIM window

System Throughput at 50% load of 2Mbps using 32 nodes



System Throughput using 64 nodes



Comparison with the DPSM

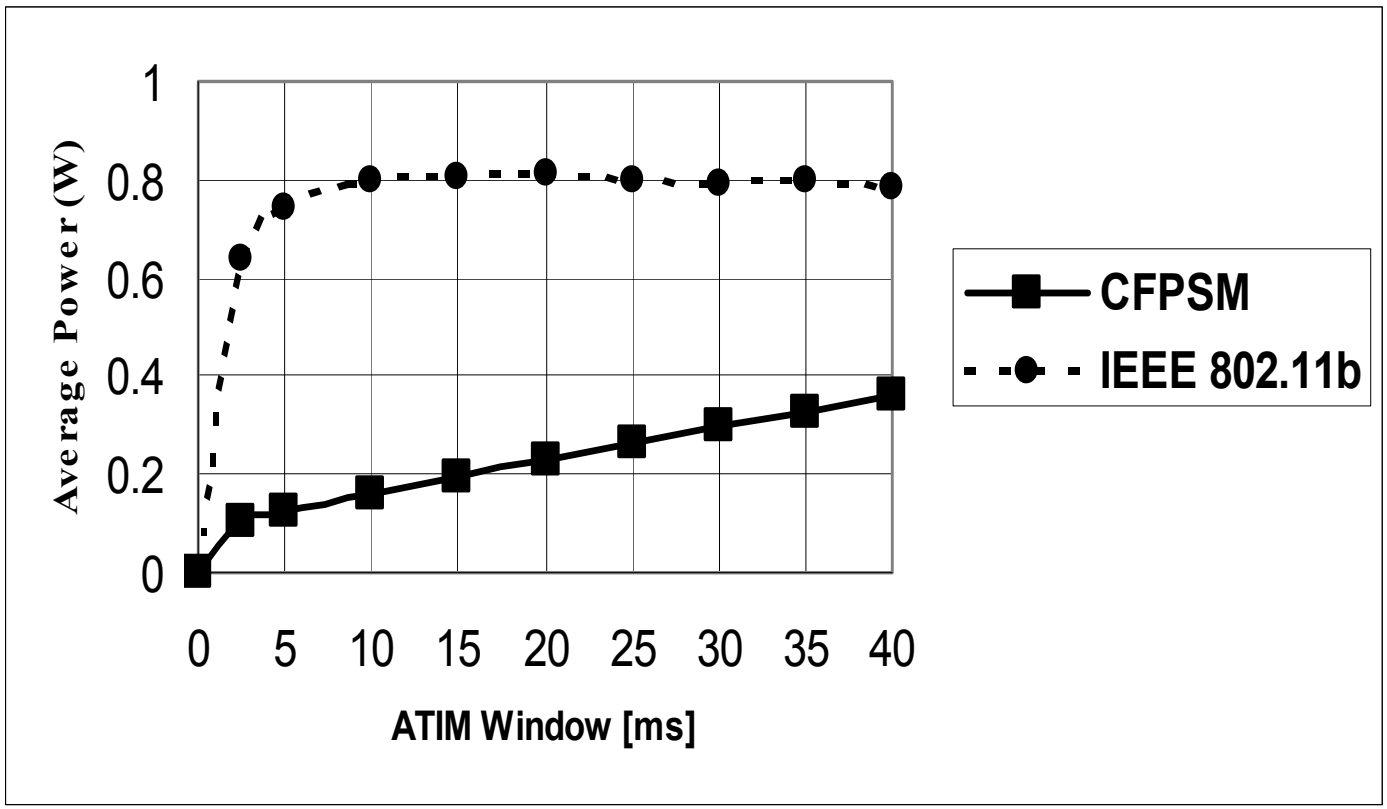
As seen from the result CFPSM performs better than

5% than DPSM in case of 32nodes.

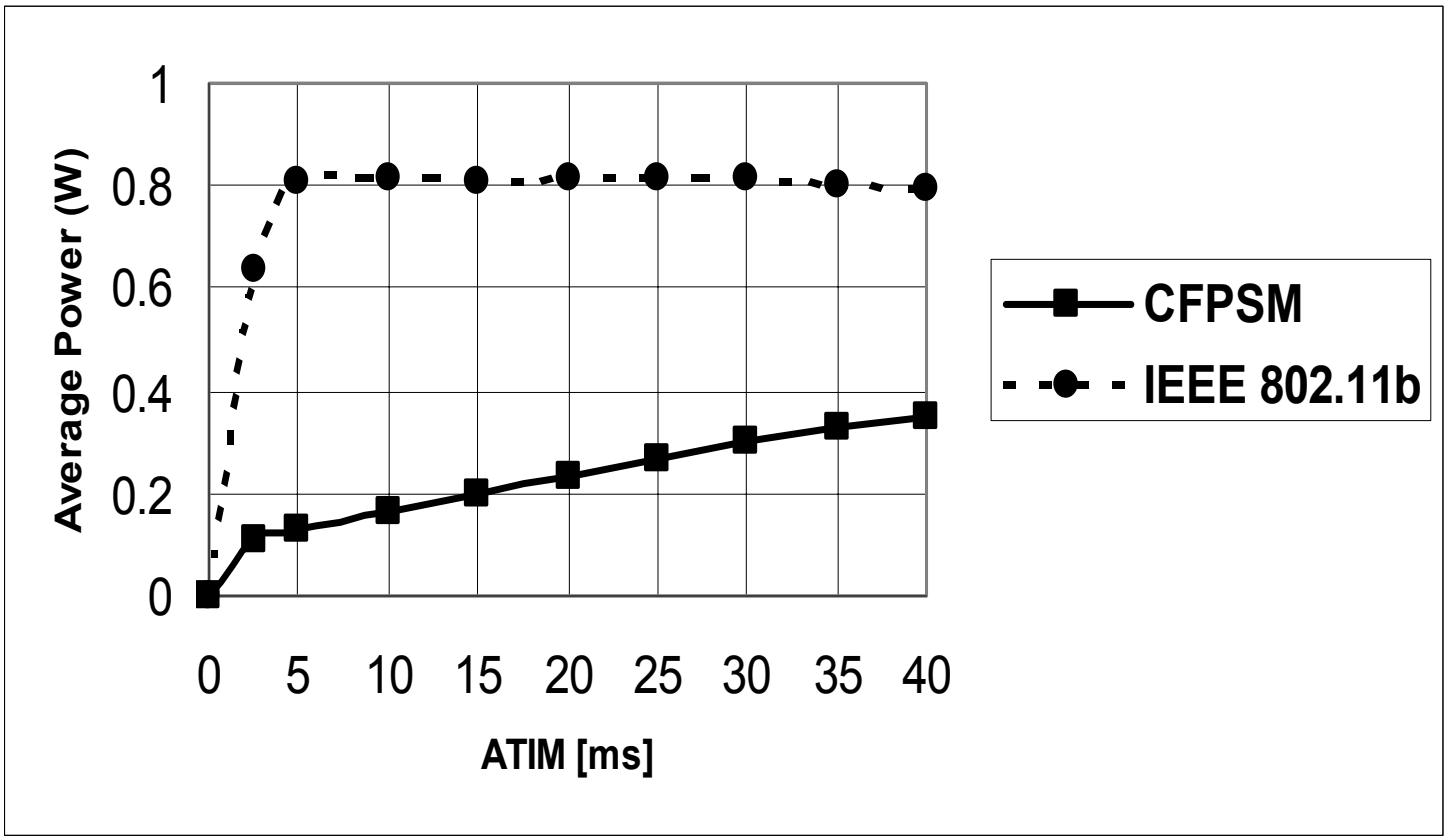
At 64 node DPSM has 733 kbps while the CFPSM has 1000 kbps for long range of ATIM window size.

Reason for higher throughput than DPSM is that DPSM is follows DCF procedure,At higher loads its performance decrease due to increase in contention for data transfer.

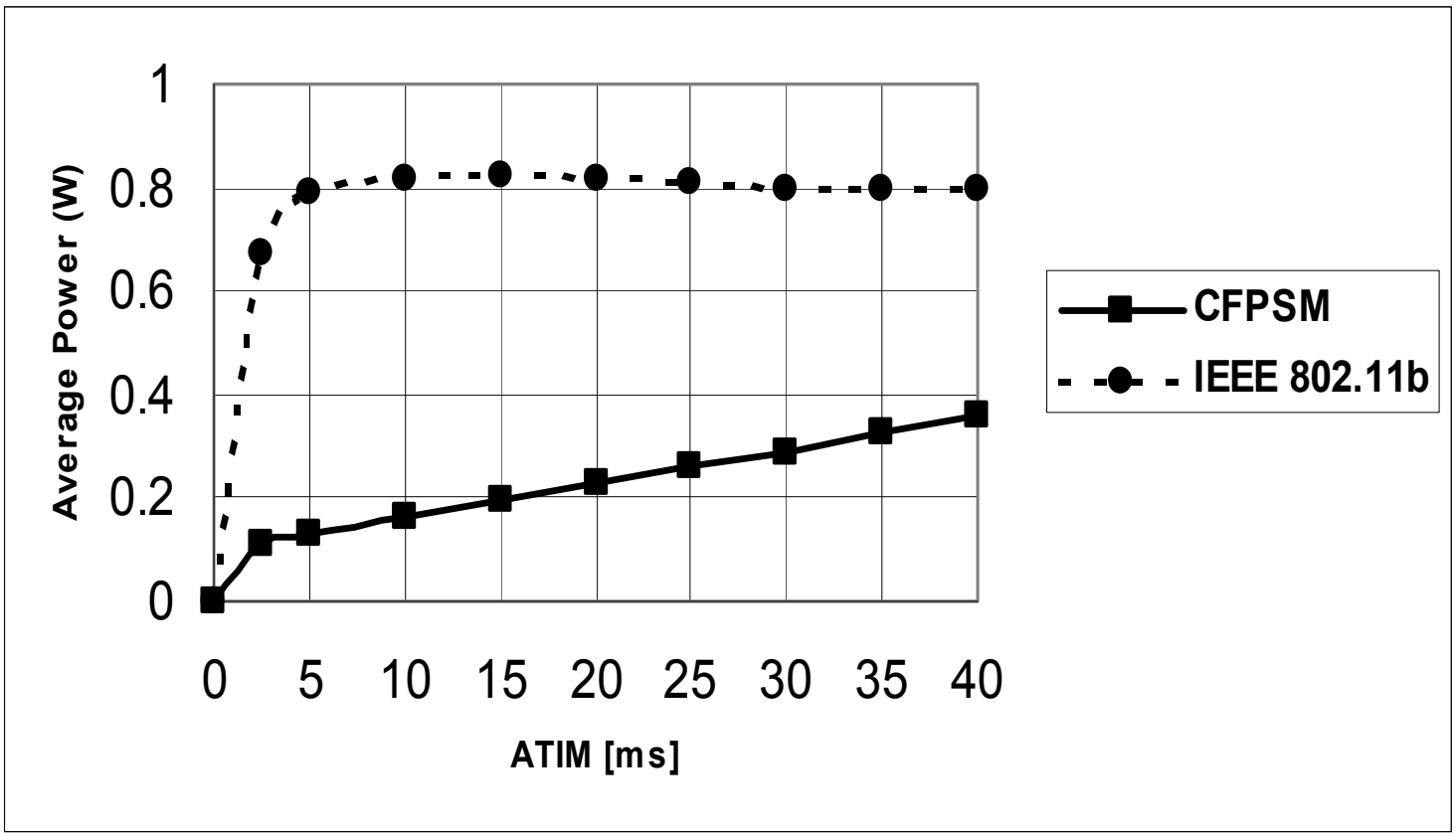
Average power at 60% load of 11Mbps



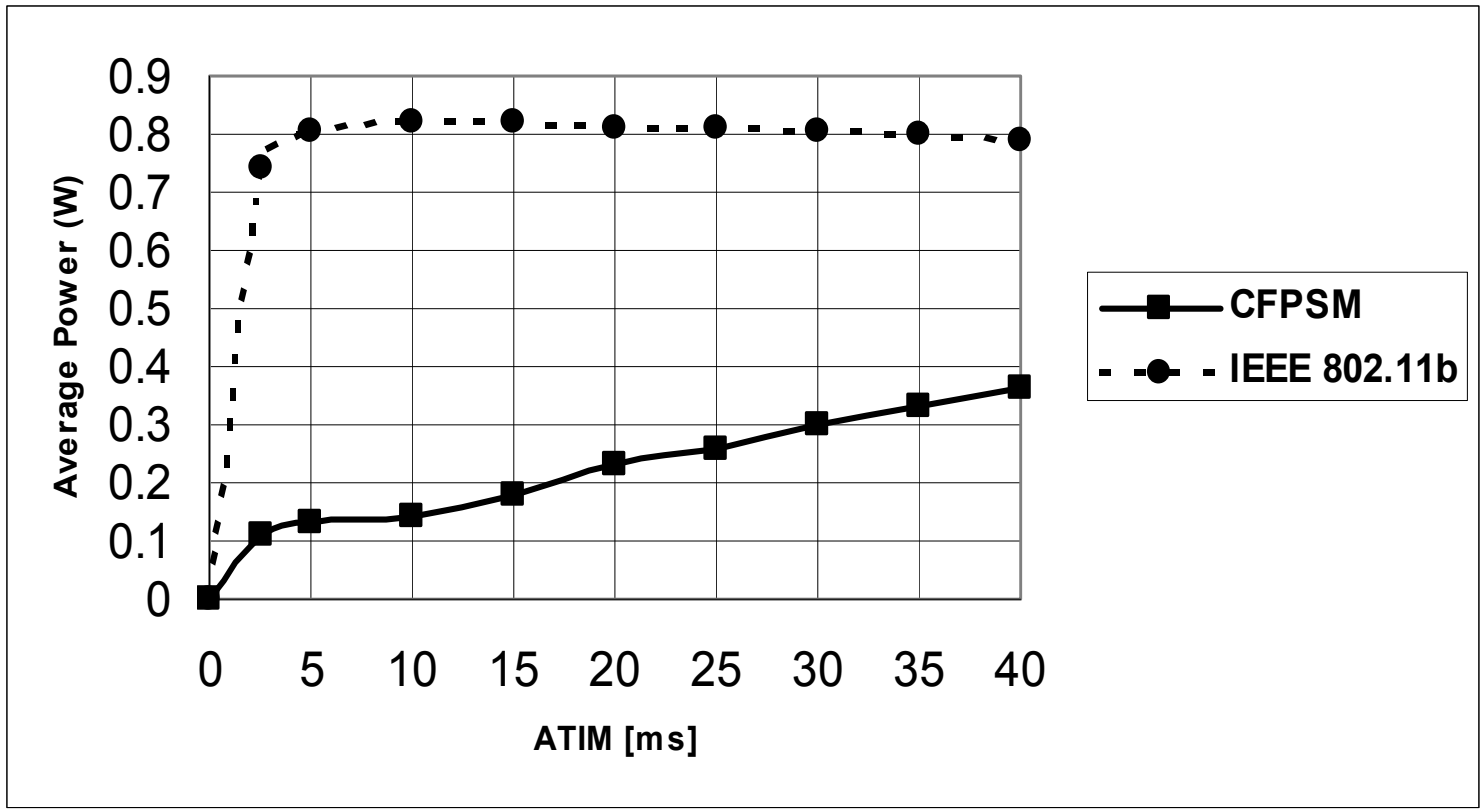
Average Power at 70% load of 11Mbps



Average Power at 80% load of 11Mbps



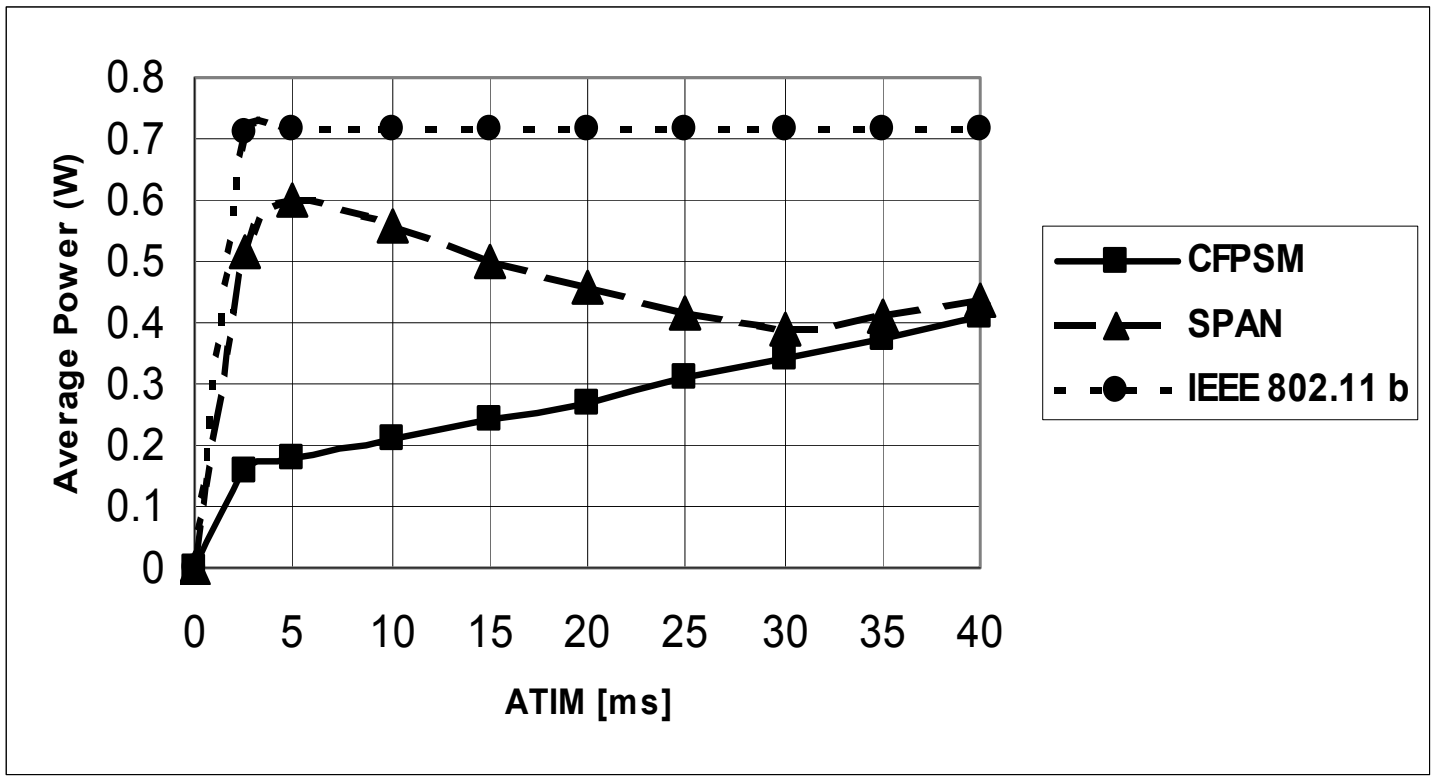
Average Power at 90% load of 11Mbps



Comparison with the 802.11 PSM

1. As seen for the result power consumption at optimal throughput is only 0.16 W as compared to 802.11 b has 0.8 W watt.
2. CFPSM has 80% improvement over the the 802.11b PSM.
3. At other loads we get 75% to 80% improvement over 802.11b

Comparison with Span

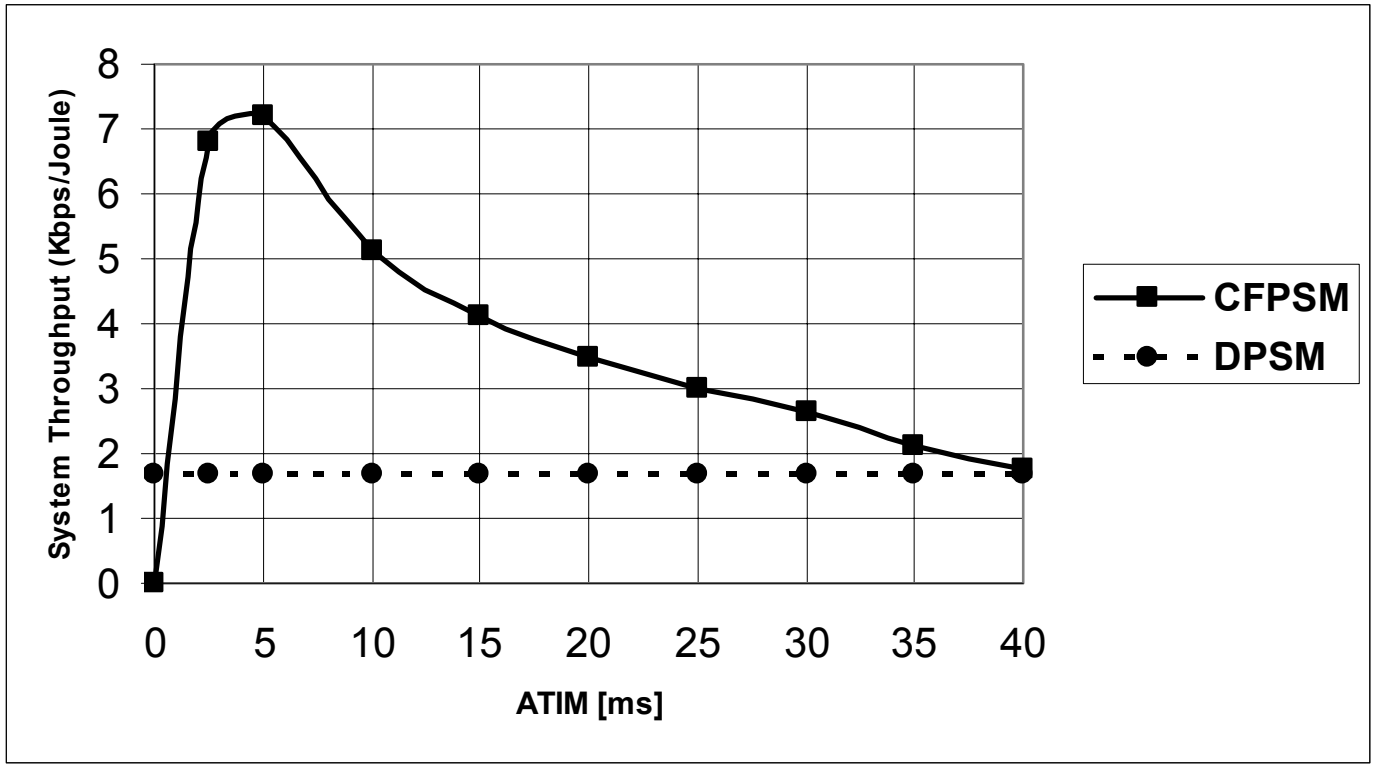


Comparison with Span

As seen from result of Broadcast mode CFPSM performs better than Span

Under optimal throughput conditions CFPSM has only 0.2 W power consumption per node as compared to 0.6W for Span .CFPSM performance is 60 % better than Span.

System Throughput/ Energy for 32 nodes using unicast mode at 2Mbps



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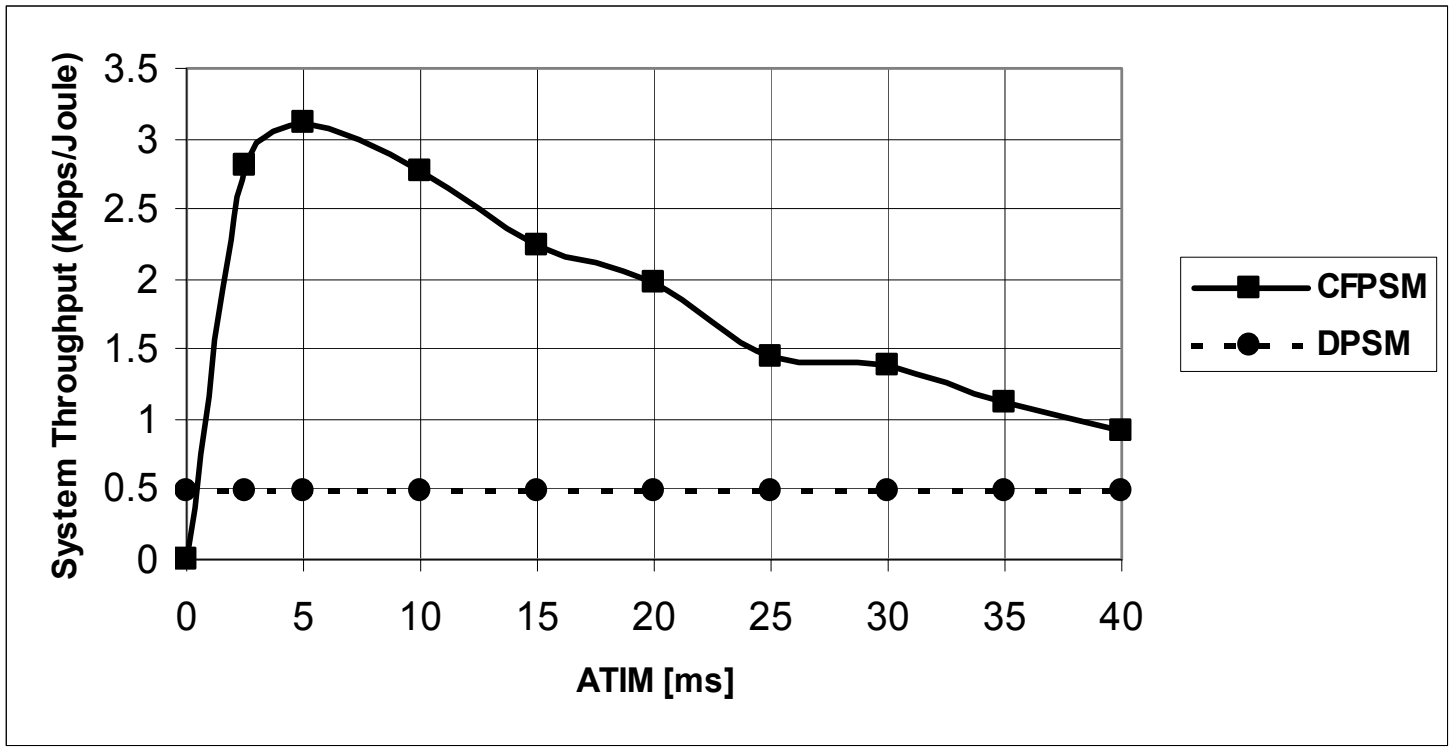


Comparison with DPSM of System Throughput/Energy

As seen from the both results of DPSM CFPSM has higher value of System Throughput/Energy(Kbps/joule)

CFPSM perform 4 times better than DPSM

Reason for high value is that CFPSM has lower power consumption and contention free data transfer and STA need not awake for full beacon period

in DPSM also STAS need not awake for full beacon period but time is more due to data gets through contention.

Limitation of CFPSM

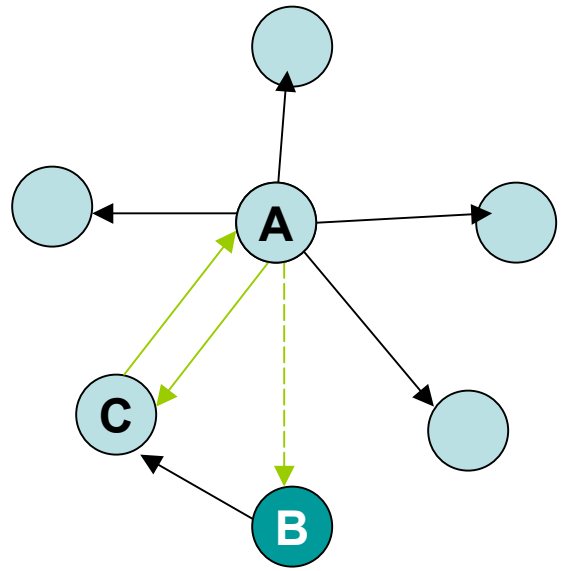
- Announce List created by all nodes in global Data structure (no concept of beacon transmitter)
- Announce Frame transmitted by last node exiting from ATIM window
- Multiple beacon transmitter are possible, which implies multiple announce list
- End of ATIM window is not synchronized so collision may occur
- Beacon period is not synchronized

- CFPSM can handle only Fixed size Data packets
- No Retransmission in CFPSM
- Traffic is generated at MAC layer
- Restriction on sender and receiver MAC addresses
- CFPSM is designed for only single WLAN

- Transmissions in CFP do not strictly follow the ATIM sequence
- How the next STA will know about its turn
- No CP Period
- No handling of broadcast traffic

Solution of Multiple Beacon Transmitter (Single WLAN)

- Beacon information has been added with ATIM/ACK
- BT use this information to synchronize with least beacon time



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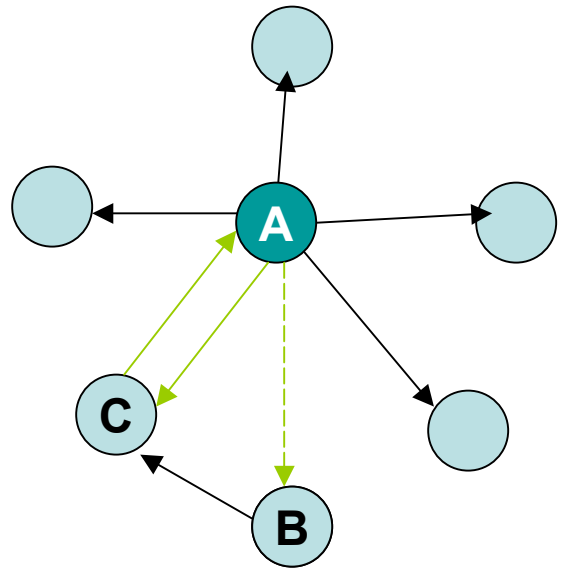
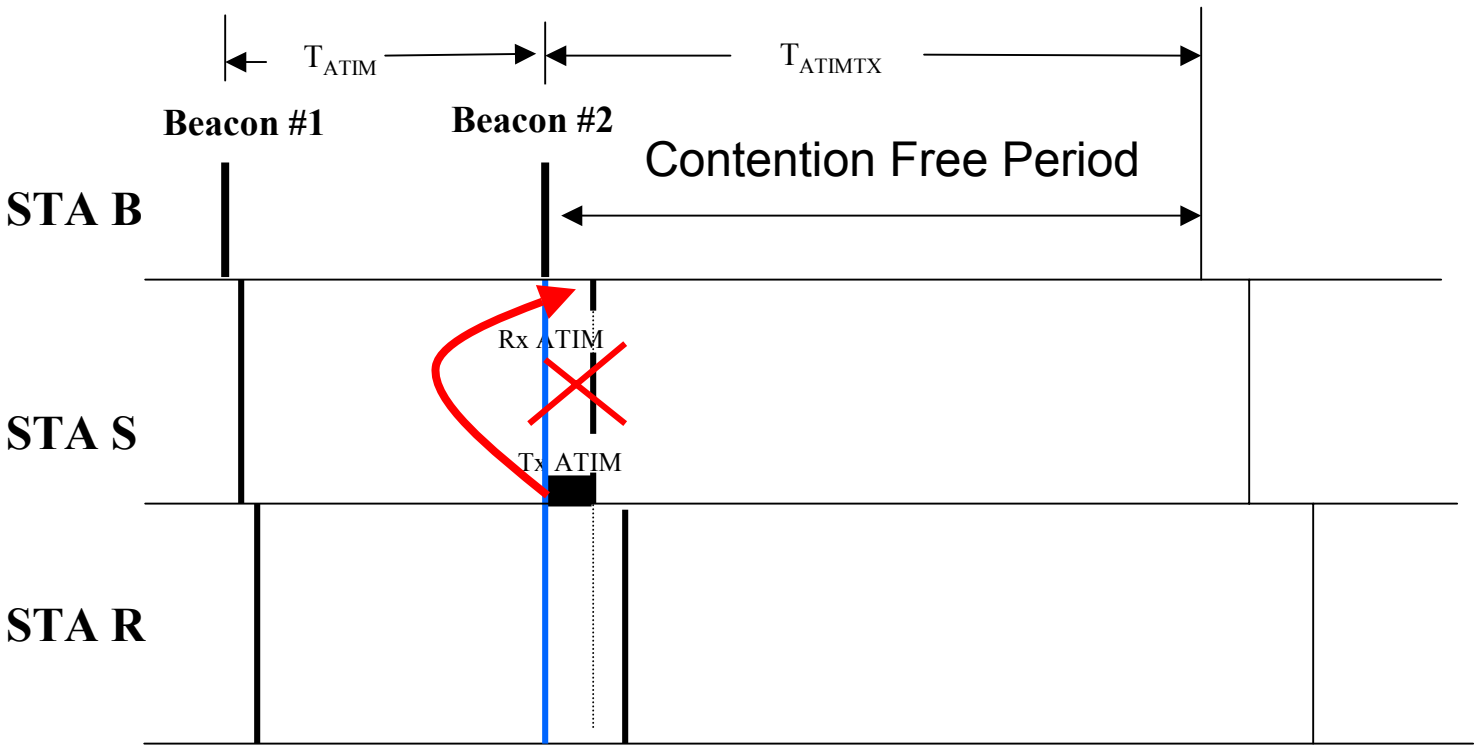
- Beacon information has been added with ATIM/ACK
- BT use this information to synchronize with least beacon time



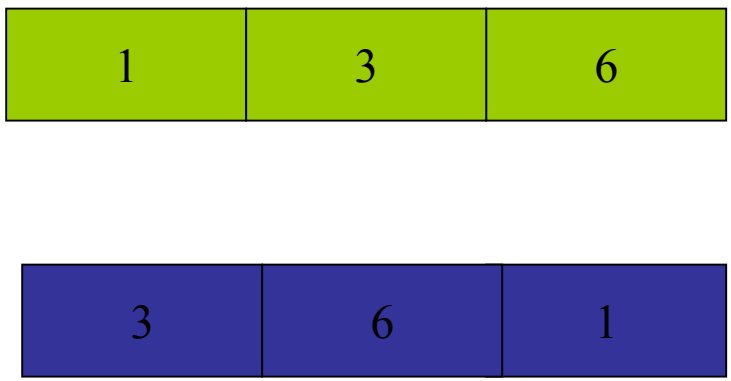
End of ATIM Window Problem



- A Node will remain awake in CP, cases
  - Exchanged ATIM-ACK, but not included in Announce List.
  - Unable to get a chance to send Data according to AL or was able to send Data but did not receive ACK from receiver (retransmission).
  - A receiver keeps awake in CP, if the exchanged number of ATIM-ACKs is more than number of frame received in CFP.

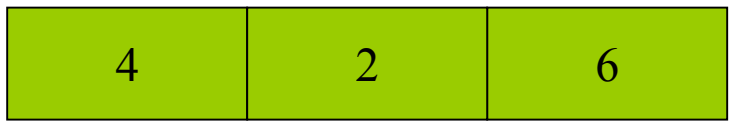
Transmissions in CFP do not strictly follow the ATIM sequence

- In CFPSM, data transmission was in the sorted order of STA address which was simple but unfair algorithm
- In enhanced CFPSM, it is on basis of ATIM transmissions
- e.g. Suppose ATIM are transmitted in following sequence (sender, receiver)
  ((3, 23),(6,26),(1,21))



How the next STA will know about its turn

- Suppose announce list



- In CFPSM

  Station 2 receive ACK of 4 and become next transmitter

  Disadvantage: A single transmission failure will cause all subsequent data transmissions to fail

- Enhanced CFPSM

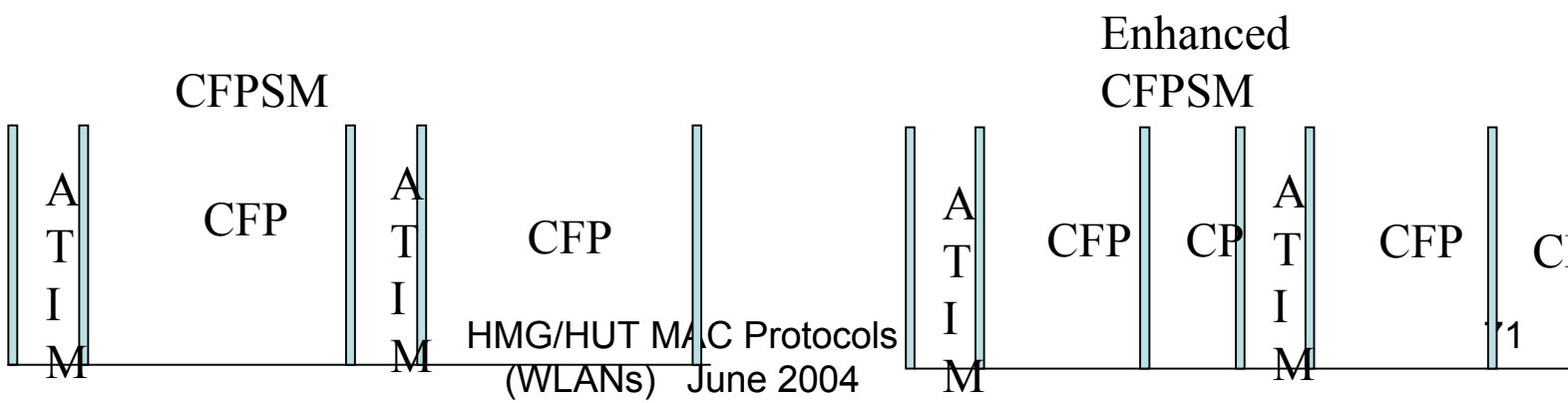
  After wake up, if channel is free, node 2 will wait for DIFS and

  will transmit data if after completion of DIFS channel is still

  free.

No CP Period

- CFPSM is tested only for power save nodes
- No Contention Period
- CP period is required for Active nodes as well for retransmissions
- CP period uses DCF procedure
- Performance shown by CFPSM is reduces due to CP period, but reliability increased

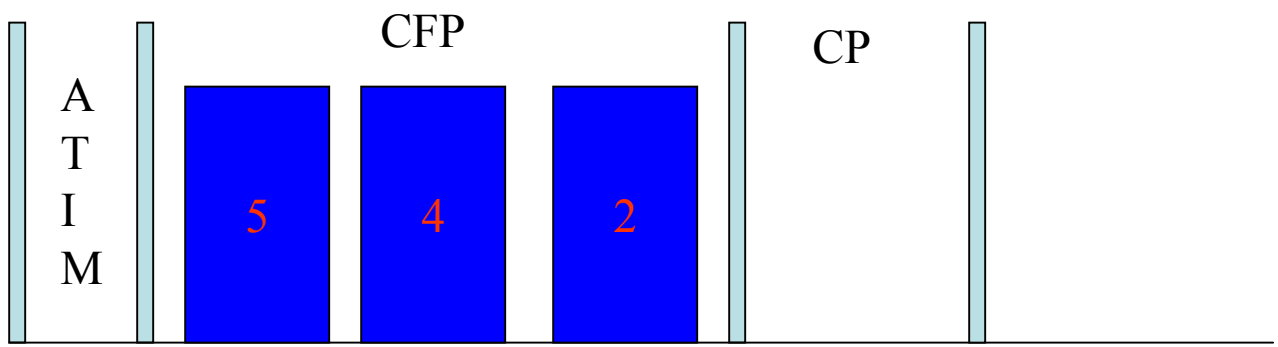


No handling of broadcast traffic

- Generally routing layer send broadcast packets to MAC layer during route finding
- In start of CF, probability of collision is much
- Broadcast frames should be scheduled late in CFP
- Broadcast frames should be given priority over unicast frames

Suppose the following node are successful in ATIM period

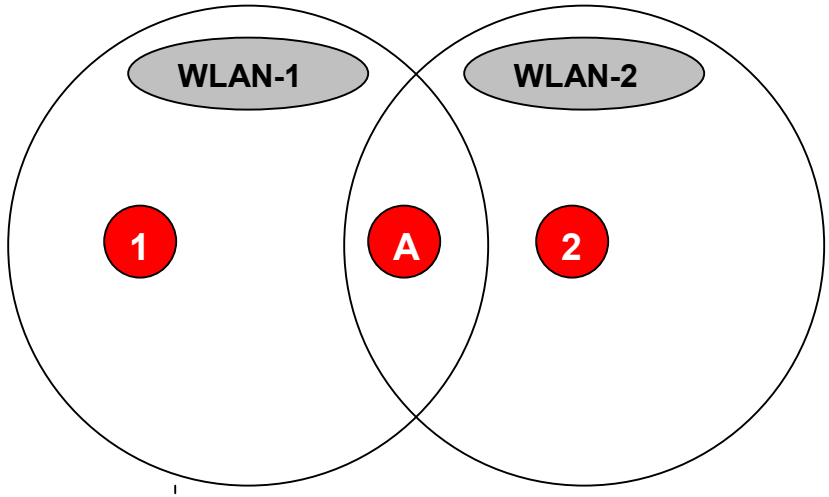
4(b) 5(u) 2(b) 9(u)



CFPSM for Multi-WLAN

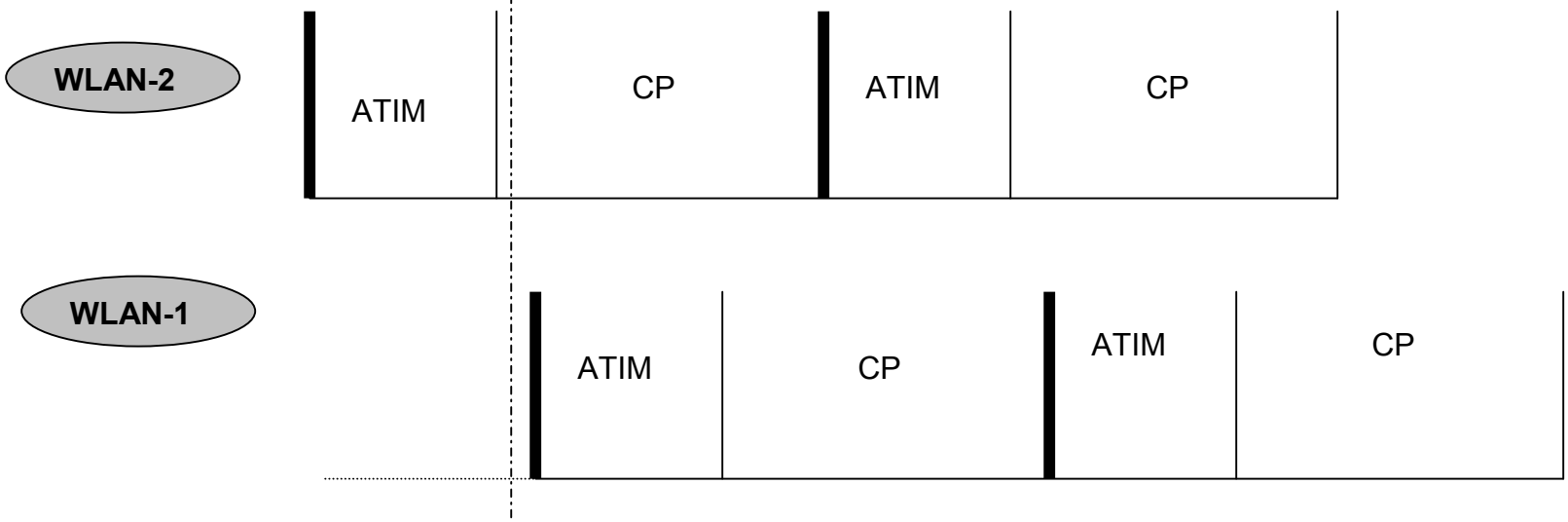
- Problems of CFPSM for Multi-WLAN Network
  - Beacon Synchronization problem
  - Beacon Transmitter Identification problem (WLAN identification and its current beacon transmitter, who will make announce list)

Why Beacon Synchronization Required in Multi WLAN Network?

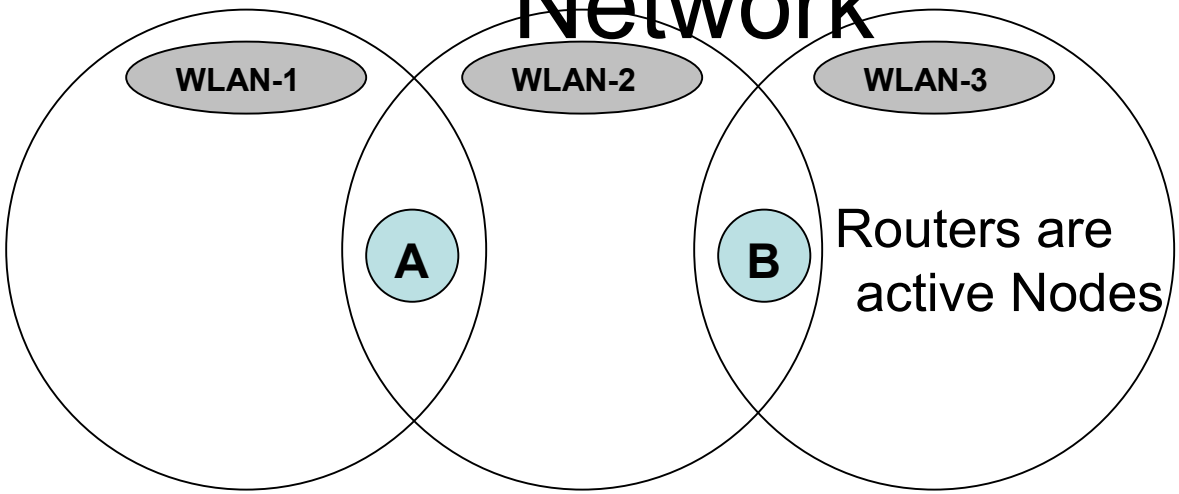


1→2
1→A→2

t1-t2 > ATIM Period

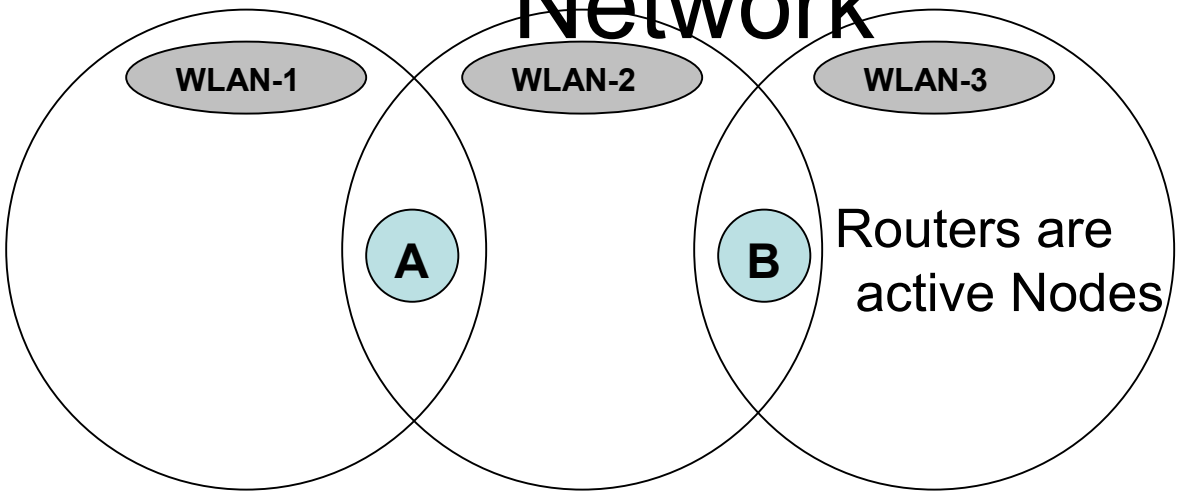


Why Beacon Synchronization Required in CFPSM for Multi WLAN Network



- Data transfer in A and B cannot be scheduled in CFP
  - They will not transmit ATIM/ACK
  - If we forcefully transfers ATIM/ACK then also there beacon period is not synchronized, so they may not be schedule.
  - If we will some how schedule them in CFP period then also they will cause contention in CFP period in other WLAN where they are not scheduled

Why Beacon Synchronization Required in CFPSM for Multi WLAN Network



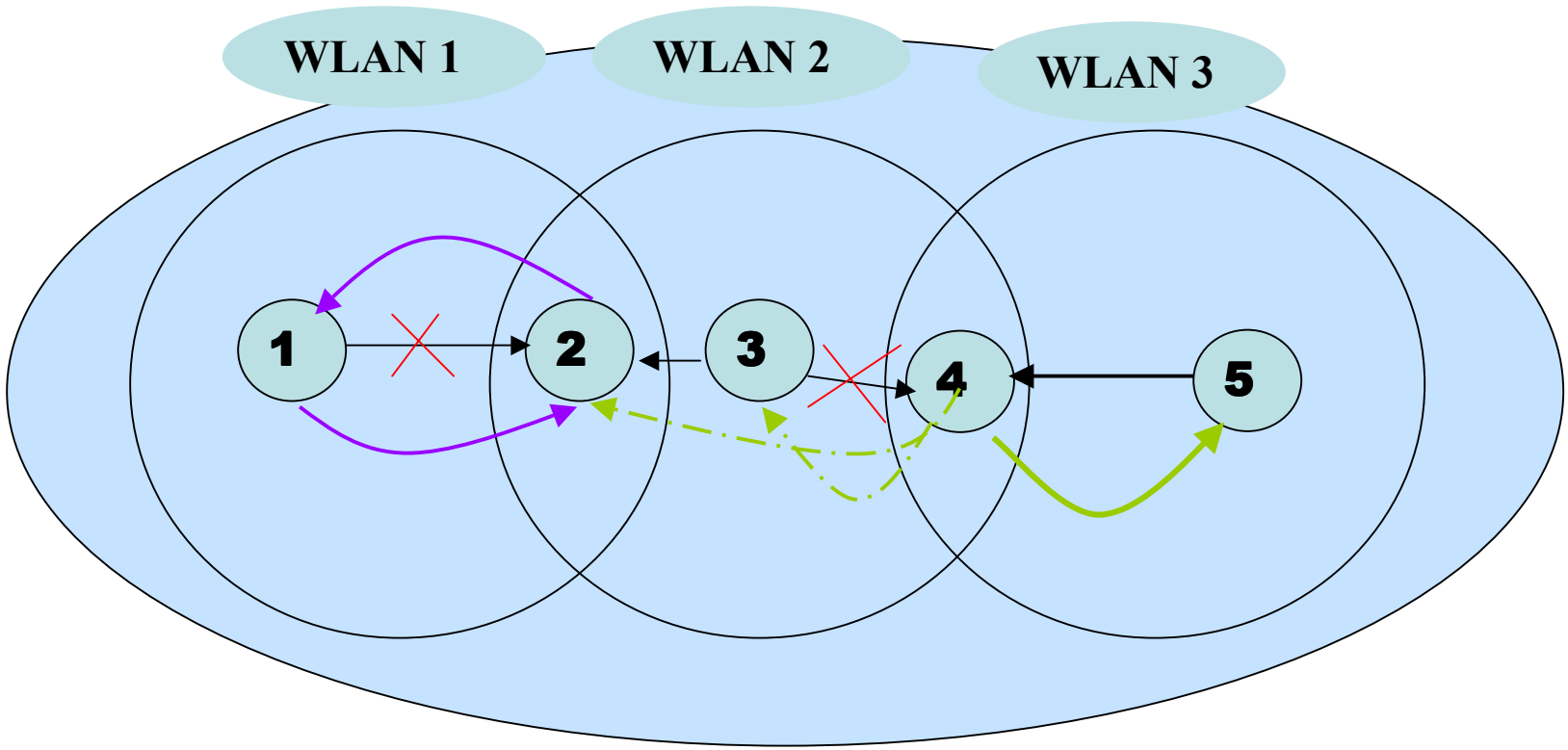
- Data transfer in A and B cannot be scheduled in CP
  - For this CP period must be synchronized, again we require beacon synchronization

Multi-WLAN Beacon Synchronization

- Each packet contains beacon time as synchronization information
- Nodes in WLANs will use this information to synchronize with the least beacon time WLAN
- After beacon periods are synchronized, we can configure ***any*** power save node as router

CASE-I [t1>t2>t3] (Beacon Synchronization)

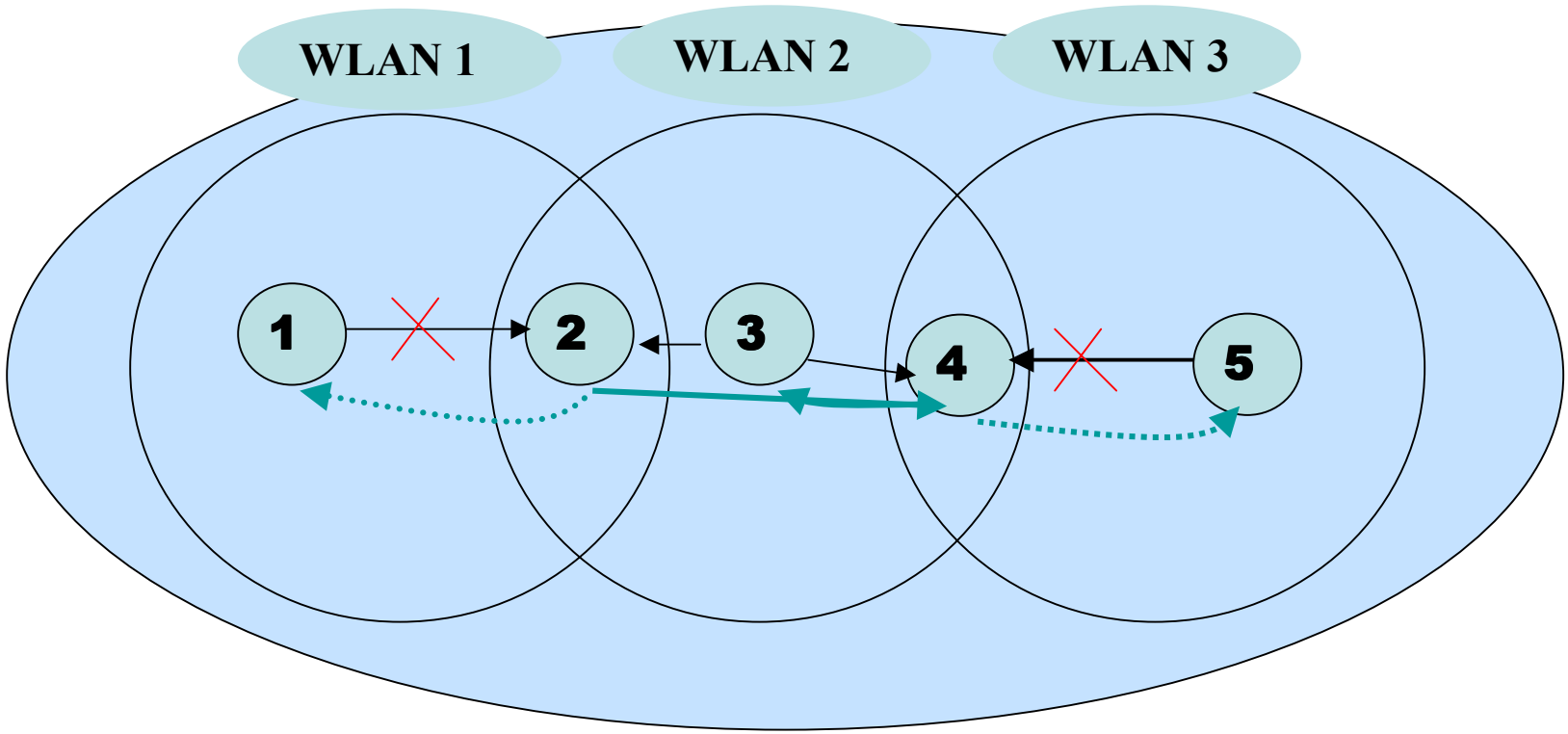
t1>t2>t3



All LAN Synchronized to t3

CASE-II [t1>t3>t2] (Beacon Synchronization)

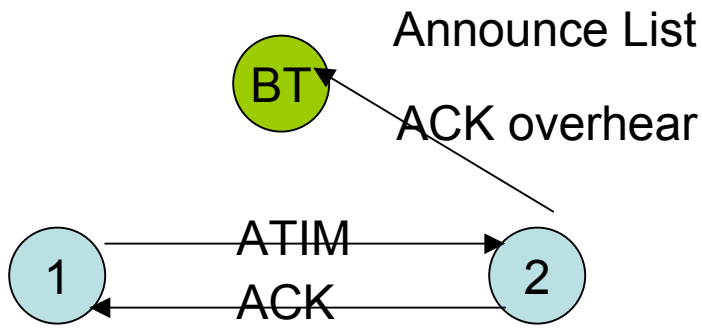
t1>t3>t2



All LAN Synchronized to t2

What is Announce List [AL] & Modified AL creation logic in Multi-WLAN

- Announce list is a sequence, in which the nodes will transmit data in CFP period.



BT will make entry in announce list only if it overhear both ATIM and ACK

Conditions for Beacon transmitter

- Beacon transmitter is the STA who is repsonsible for making AL for its corresponding WLAN
- Conditions
  - Each STA should have its beacon transmitter in hearing range
  - Beacon transmitter should make all entries corresponding to all STA in its range only
  - Each STA should choose the beacon transmitter with minimum beacon time in its range
  - Announce List should be received successfully by each STA

Beacon transmitter identification procedure in Multi-WLAN

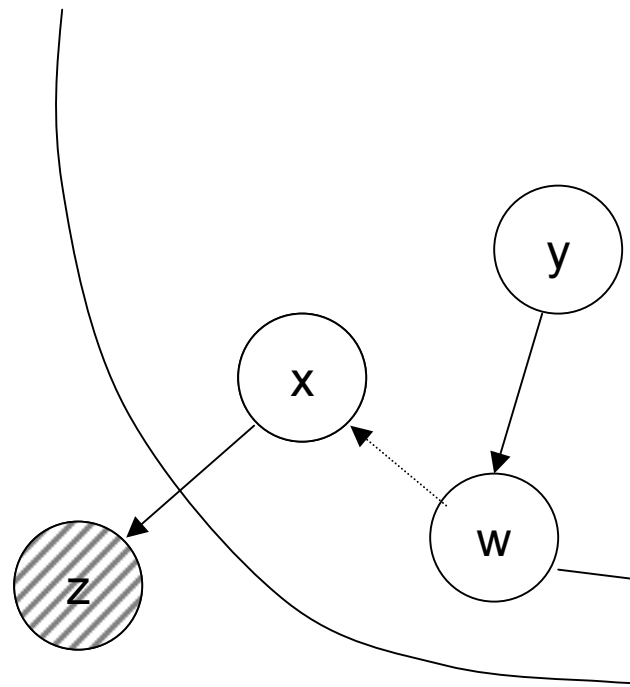
- **Insertion**
  - Each STA has a BTinRangeList which has entries corresponding to each beacon transmitter in range of that STA.
  - If STA received a beacon, it will insert the sender of this packet into its BTinRangeList
  - If STA overhears a ATIM or its ACK and sender of this ATIM or ACK is beacon transmitter, STA will insert this sender into BTinRangeList.
  - Each STA will choose its current beacon transmitter from this list, having minimum beacon time

Beacon transmitter identification procedure in Multi-WLAN…(contd.)

- **Deletion**
  - Suppose a STA A overhears or receive a packet in which sender is STA B which is also BTinRangeList of A.
  - If the address of that STA B not equal to beacon transmitter of STA B
  - STA B is no longer beacon transmitter.
  - STA A will delete the entry corresponding to STA B from its BTinRangeList
- **Self-Addressed ATIM**
  - Each beacon transmitter will send some self addressed dummy packets in ATIM period
  - This will ensure that each STA in beacon transmitter range will be able to know its existence
- **Every STA will accept AL from its current beacon transmitter only**

Beacon transmitter identification procedure in Multi-WLAN…(contd.)

- Suppose node x is a beacon transmitter and in hearing range of node y
- Node z assumes node x as its beacon transmitter and node w assumes y as its beacon transmitter
- Node x received a packet from w with less beacon-time so node x will accept node y as its beacon transmitter.
- When node z will overhear a packet from node x, where y



Beacon transmitter identification procedure in Multi-WLAN…(contd.)

- In same beacon period if node z came to know about any other beacon transmitter in its hearing range, it will accept that beacon transmitter as its beacon transmitter and will transmit according to list of this beacon transmitter otherwise go to sleep for CFP period
- Nodes only accept AL from its beacon transmitter
- If nodes fails to transmit in CFP, will transmit in CP

References

1.IEEE 802.11, 1999 Edition, IEEE Standards for Information Technology-- Telecommunications and Information Exchange between Systems -- Local and Metropolitan Area Network -- Specific Requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

2.IEEE 802.11b-1999 Supplement to 802.11-1999, Wireless LAN MAC and PHY specifications: Higher speed Physical Layer (PHY) extension in the 2.4 GHz band.

3. Vimal Kumar Khanna , H M Gupta, and Satyavardhan Maheswari, “Contention Free Data Transfer in IEEE 802.11 Ad-hoc WLAN”,IEEE TENCON,2003 held at Banglore.

4 Vimal Kumar Khanna, H M Gupta, and Satyavardhan Maheswari, “A high Throughput and Low Power Ad-hoc Wireless LAN protocol”, IEEE Transaction on wireless communication under review.

5 Vimal Kumar Khanna, H M Gupta and Satyavardhan Maheswari, “Throughput Improved and Power saving in Wireless LAN”, IETE Technical review.

10.Vimal K. Khanna, S. Singh, "***An Improved Piggyback Ethernet Protocol and its Analysis***", Computer Networks and ISDN Systems, Elsevier Science, Volume 261. pp.1437-46, 199

11.http://**www.pdos.lcs.mit.edu/span**

12.B. Crow, I. Widjaja, J. Kim, P. Sakai, "***IEEE 802.11 Wireless LANs***", IEEE Communications Magazine, pp.116-126, Sept 1997.

13. K. Pahlavan, A. Zahedi, P. Krishnamurthy, "***Wideband Local Access: WLAN and Wireless ATM***", IEEE Communications Magazine, Nov 1997.

17. Fullmer, J. Garcia-Luna-Aceves, "***Solution to Hidden Termi***

Problems in Wireless Networks", ACM SIGCOMM, Sept 1997.

18.J.C. Chen, K. M. Sivalingam, P. Aggrawal and S. Kishore,

"***Comparison of MAC protocols for Wireless Networks***

Based on Battery Power Consumption", Proceedings of

IEEE INFOCOM, pp.150-157, April 1998.

19.Zorzi, .R. R. Rao, "***Error Control and Energy Consumption***

Communications for* Nomadic *Computing", IEEE

Transactions on Computers, Vol. 46, pp. 279-289,March 1997.

20.P. Lettieri, M. B. Srivastava, "***Adaptive Frame Length Control for Improving Wireless Link Throughput, Range and Energy Efficiency***", Proceeding of IEEE INFOCOM, pp. 564-571, April 1998.

21.J. Lorch, A. J. Smith, "***Software strategies for Portable Computer Energy Management*",** IEEE Personal Communications Magazine, 5(3), pp. 60-73, 1998

22.P. Littieri, M. B. Srivastava, "***Advances in Wireless Terminals***", IEEE Personal Communications, pp. 6-19, February 1999.

23. H. Woesner, J. Ebert, M. Schlager, A. Wolisz, "***Power – Saving Mechanisms in Emerging Standards for Wireless LANs: The MAC Level Perspective***", IEEE Personal Communications Magazine, pp. 40-48, June 1998.

. 24 .Eun-Sun Jung, Vaidya*, N.H* "***An energy efficient MAC protocol for wireless LANs***" Proceedings of IEEE INFOCOM 2002, Volume 3, pp. 1756 -1764, June 2002.

25. C.B Chiasserini, R.R Rao, "***Energy Efficient Battery Management***", IEEE Journal on Selected Areas in Commun., Vol. 19, No. 7, pp.1235-1245, July 2001.

26.C. B Chiasserini, R. R. Rao, "***Improving Battery Performance by using Traffic Shaping Techniques***", IEEE Journal on Selected Areas in Communications, Vol. 19, No. 7, pp. 1385-1394, July 2001.

. 27. L. M. Feeney, M. Nilsson, "***Investigating the Energy Consumption of a Wireless Network Interface in an Ad Hoc Networking Environment***", IEEE INFOCOM, pp. 1548-1557, 2001.

28. K. Jamieson, "***Implementation of a Power Saving Protocol for Adhoc Wireless Networks***", M S Thesis, Department of Electrical Engineering and computer Science, Massachusetts Institute of Technology, February 2002.

29.http://www.isi.edu/nsnam/ns/ns-build.html

30. B. Chen, K. Jamieson, H. Balakrishnan, R. Morris.
"***Span: An Energy-Efficient Coordination Algorithm for***
Topology Maintenance in Ad Hoc Wireless Networks",
ACM Wireless Networks Journal, Volume 8, Number 5,
pp.481 - 494. September 2002.