Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [NICT's MAC Proposal In Response to Call For Contribution With Simulation Results]
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Re: [Response to call for contribution of 15.8 PAC

Abstract: [MAC proposal for IEEE802.15.8]

Purpose: [This document is to provide a MAC mechanism]

NICT's MAC Proposal In Response to Call For Contribution With Simulation Results

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Purpose of This Document

- This document presents corresponding simulation results on the performance of NICT's MAC proposal which was submitted and presented in response to call for contribution (14-0125-01, 14-0126-00).

Acronyms Used In This Document

#: “Number of”

Ch: channels

I-PD: Initiator PD

J-PD: Joiner PD

Disp: Dispersion of start times of I-PD

I-PD seen by J-PD: TS beacon received

J-PD Joined: Received TB beacon with ID in list

PHY Parameters Used In Simulations

Parameter	Value
PHY	BPSK(1/2)
Symbol rate	1 MHz
Data rate	0.5 Mbps
Bandwidth	2MHz
Number of channels (@2.45 GHz)	16 (5MHz Spacing)
TX Power	20dBm
Carrier-Sense threshold	-109.5 dBm
Channel loss (below rooftop, 2.45GHz)	DCN-0459-08, p. 16
Es/N0 : BER table	DCN-0058-01
Power Consumption (@3.6V)	Tx: 11.3 mA Rx: 13.5 mA Standby: 26 uA

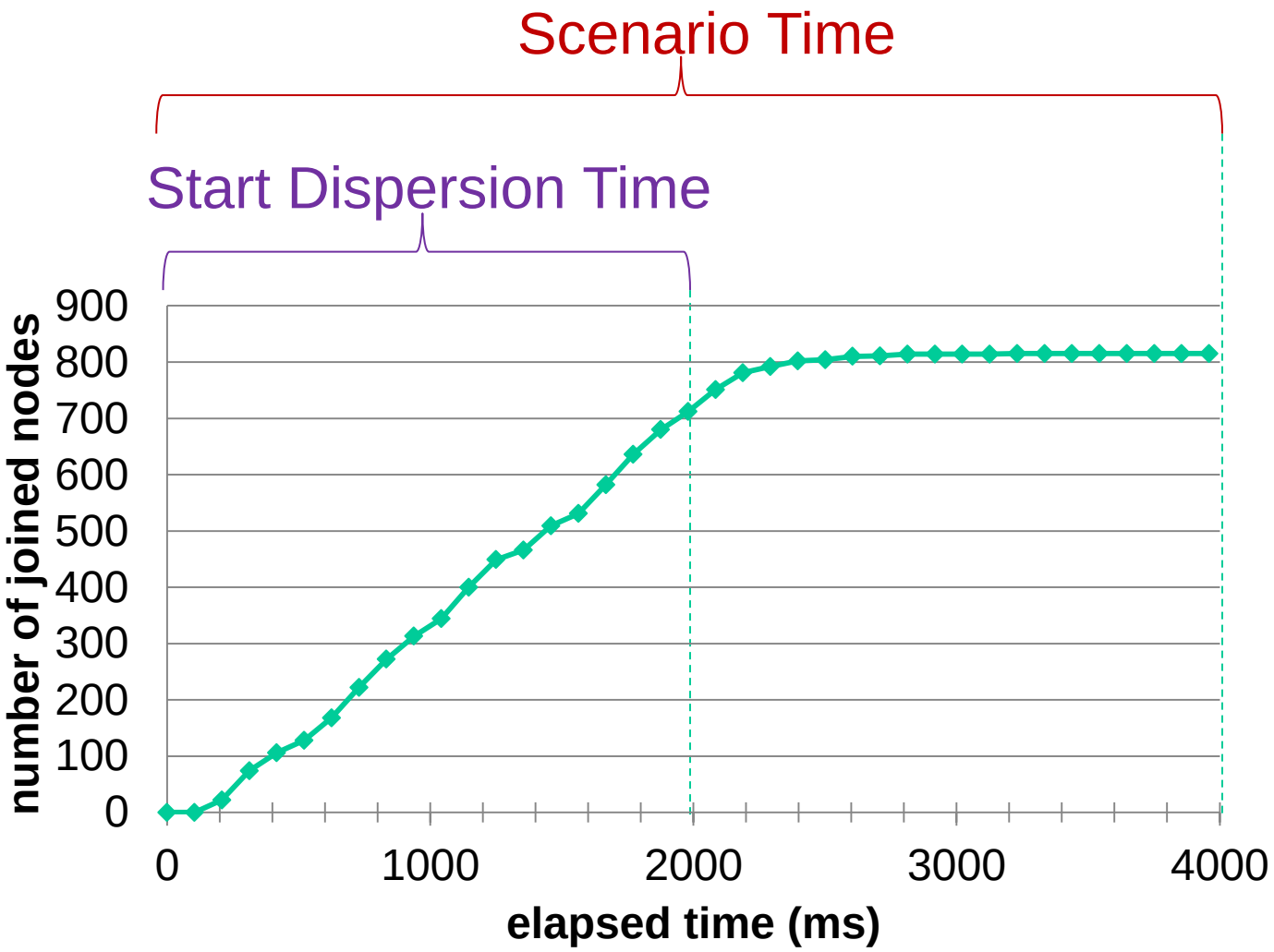
MAC Parameters Used In Simulations

Parameter	Value
TS Beacon data size	16 bytes (airtime: 0.256ms)
TB Beacon Data size	320 bytes (airtime: 6.24ms) [20 x 16 bytes]
Join Request Data Size	16 bytes
Application Data Size	512 bytes
Superframe period (TcoMIN_duration)	102.40ms
TB slot duration	10 .240ms
CFP duration	46.080ms
CAP duration	46.080ms
Sensing time for TS beacon (TcoMIN_cca)	0.256 ms
Maximum number of beacons before re-sense (NcoMax_send)	3

Large Scale Simulation Scenario

- Layout
  - 500m x 500m
  - 2-stage drop, with 100m spread range for each drop
  - Static Mobility
- I-PD “turn on”
  - at random times during an initial “dispersion” time (to avoid extreme case of all starting at the same time)
- Simulation time
  - 4 seconds, corresponding to ~ 40 periods

Simulation Scenario



Proposed Common Mode

- There shall be one and only one common mode at each frequency band that is dedicated to PAC.
- A common mode shall use a assigned fixed RF channel, and have fixed PHY parameters including modulation, channel coding, and data rate.
- All PDs shall be able to operate at the common mode.

Reason: Fixed RF channel and PHY parameters guarantee interoperability among PDs.

Operations

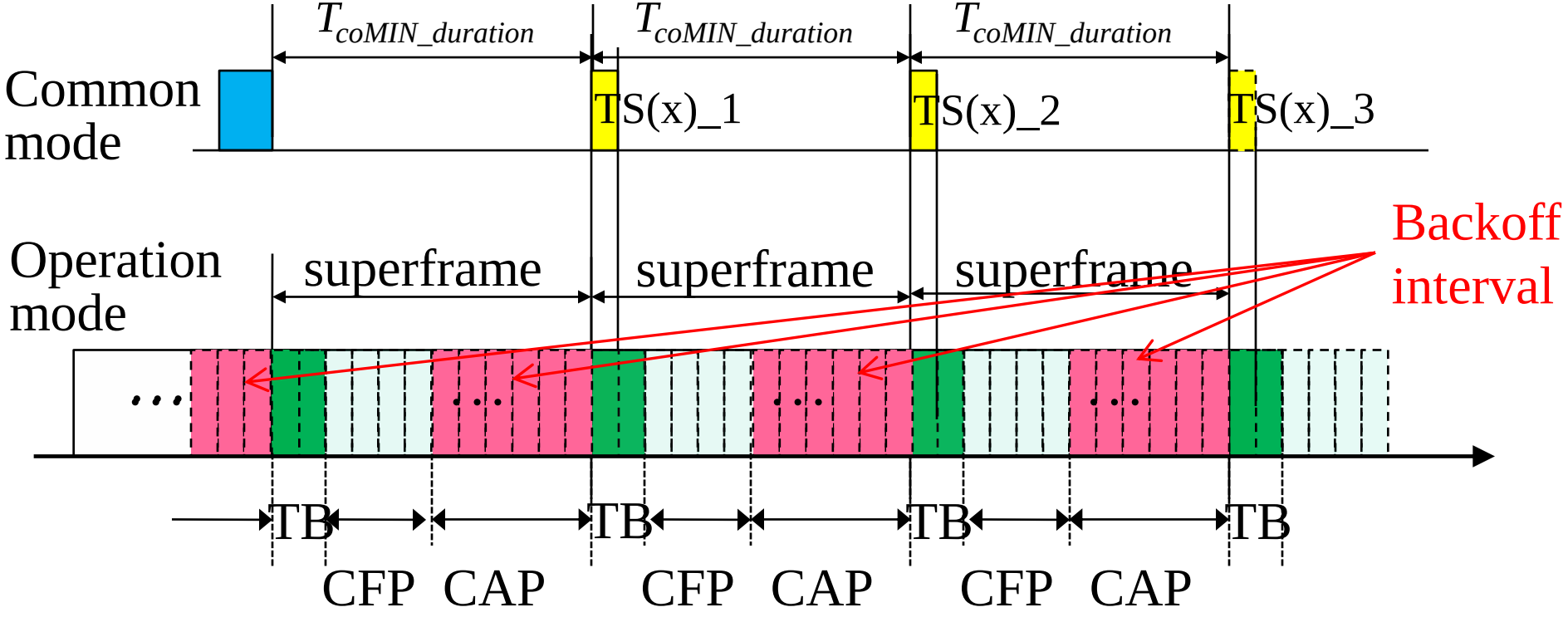
- I-PD Procedure
  - broadcast TS beacons in the common channel
  - broadcast TB beacons during TB in group channel
  - broadcast application packets during CFP after receiving a Join request
- J-PD Procedure
  - initially receive TS beacons in common channel and then switch to group channel
  - receive TB beacons in the TB slot, and transmit Join Requests during CAP

Policy of Using Common Mode

Depending on the number of available channels, the following should be considered.

- Besides emergency message transmission, to decrease scanning latency, it is desired to use common mode only for starting discovery, or for initiating a PAC group.
- Common mode should not be used in operations or communications for an established PAC group.

Proposed Superframe Structure



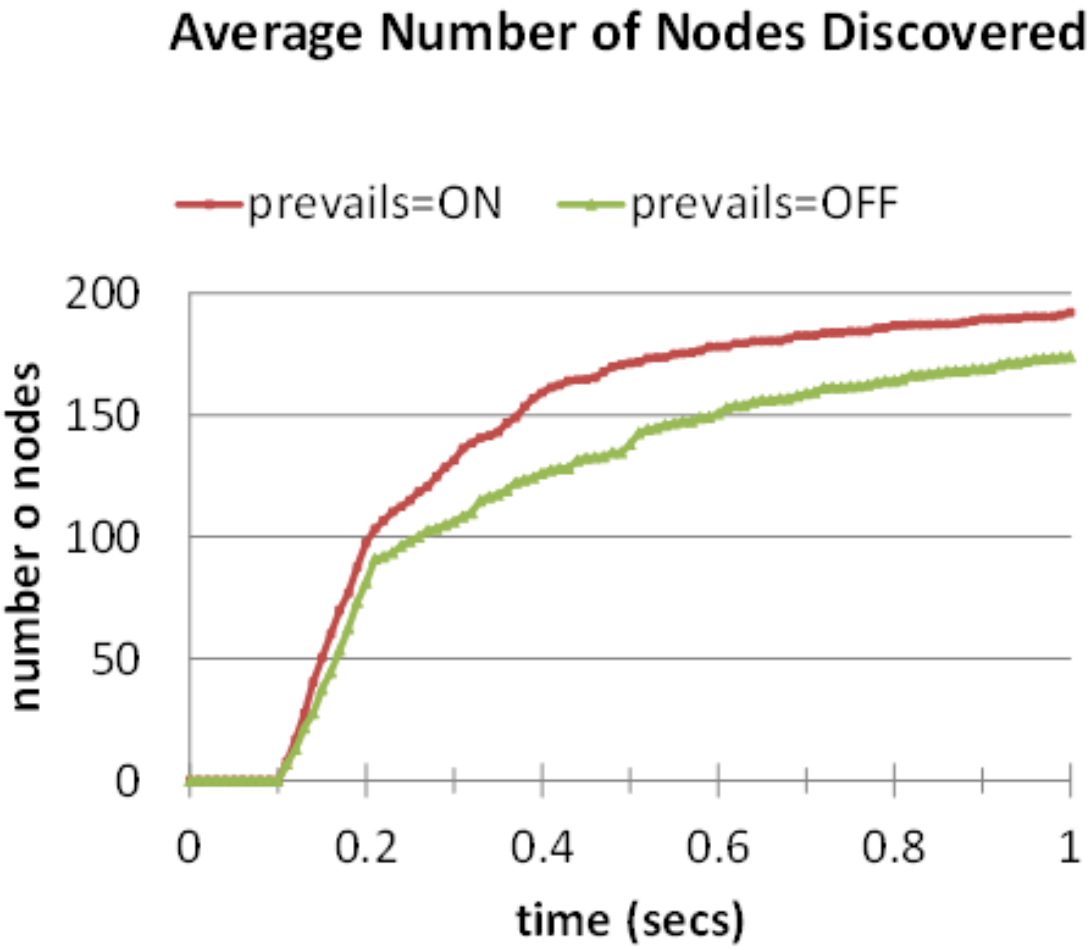
- Operation within an operation mode is based on a superframe structure, which includes a temporary beacon (TB), CFP, and CAP. The clock of TB is synchronized to the first TS.
- **The length of a superframe is equal to $T_{coMIN\_duration}$**

Simulation On Discovery

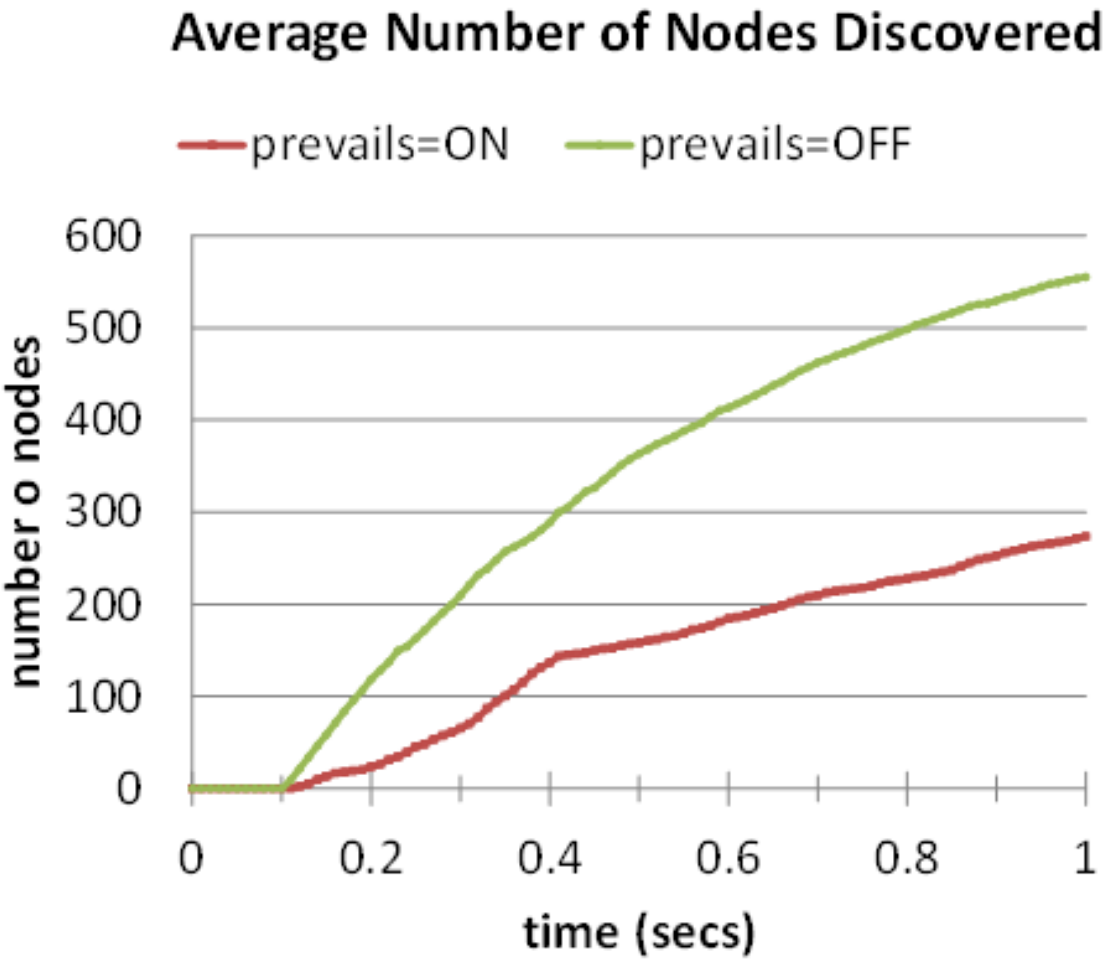
Simulation Scenarios

- Common channel only
- All PD transmitting according to common-channel MAC protocol
- Two versions of the MAC protocol
  - “prevail=ON” : Beacon transmission is given priority over reception i.e., a reception will be interrupted to transmit beacon.
  - “prevail=OFF”: Reception is given priority over transmission i.e., a beacon transmission is cancelled (deferred one period) if the node is already receiving when it is time to send a beacon

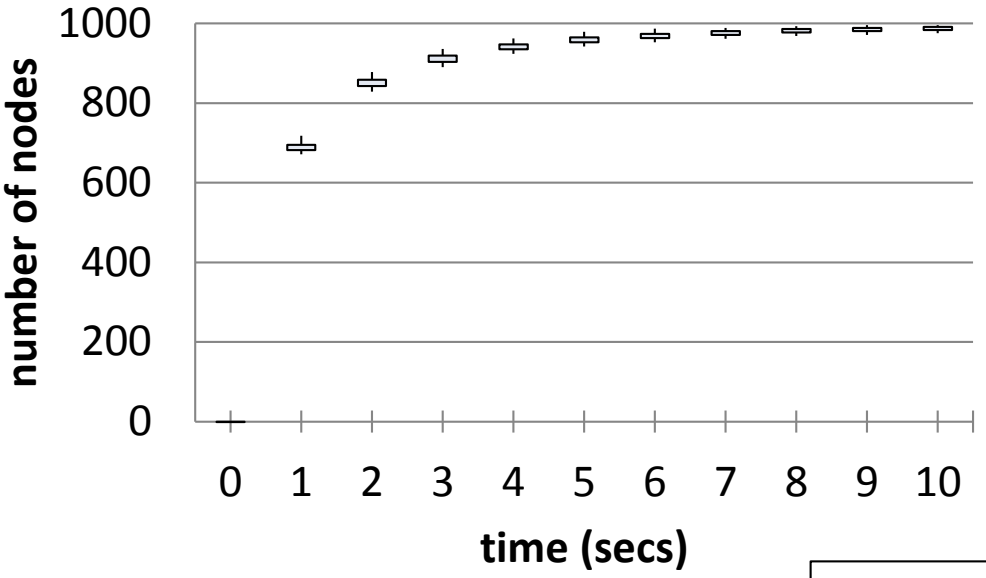
Low Density Case (200 nodes)



High Density Case (1000 nodes)



Results for 10 Seconds (1000 nodes)



* Plot symbol shows range of distribution (max, mean+sd, mean-sd, min)

Conditions:

- ts-prevail=OFF
- NcoMax=3, (See 0381-00)
- Nodes are dropped randomly inside circle with 50m diameter

Simulation on Association

Association Procedure

i. The I-PD broadcasts an invitation (active scanning) with TS including information of necessary IDs, selected operation mode (including channel), and a group clock.

ii. When a joiner PD (J-PD) scans the invitation (passive scanning) at common mode, it moves to the selected operation mode announced in (i). Accounting from the start of TS, the joining PD waits for a duration of TB+CFP. Then, it sends joining request including its ID information with a random backoff within a duration of CAP.

Association Procedure (continual)

iii. When a J-PD scans the TS in an iteration, it should calculate the difference between t_now and t_start. If t_start is within a CAP, the J-PD takes random backoff between t_start and the end of CAP and sends joining request. If t_start is out of a CAP, it waits until the next CAP before sending request.

iv. I-PD scans the selected operation mode (passive scanning), registers the J-PDs and distributes a list of the registered PDs within the temporary beacon (TB) at the selected operation mode.

v. J-PDs that had sent joining requests but are not included in the distributed PDs list should repeat the process of (ii) and (iii).

Association Latency

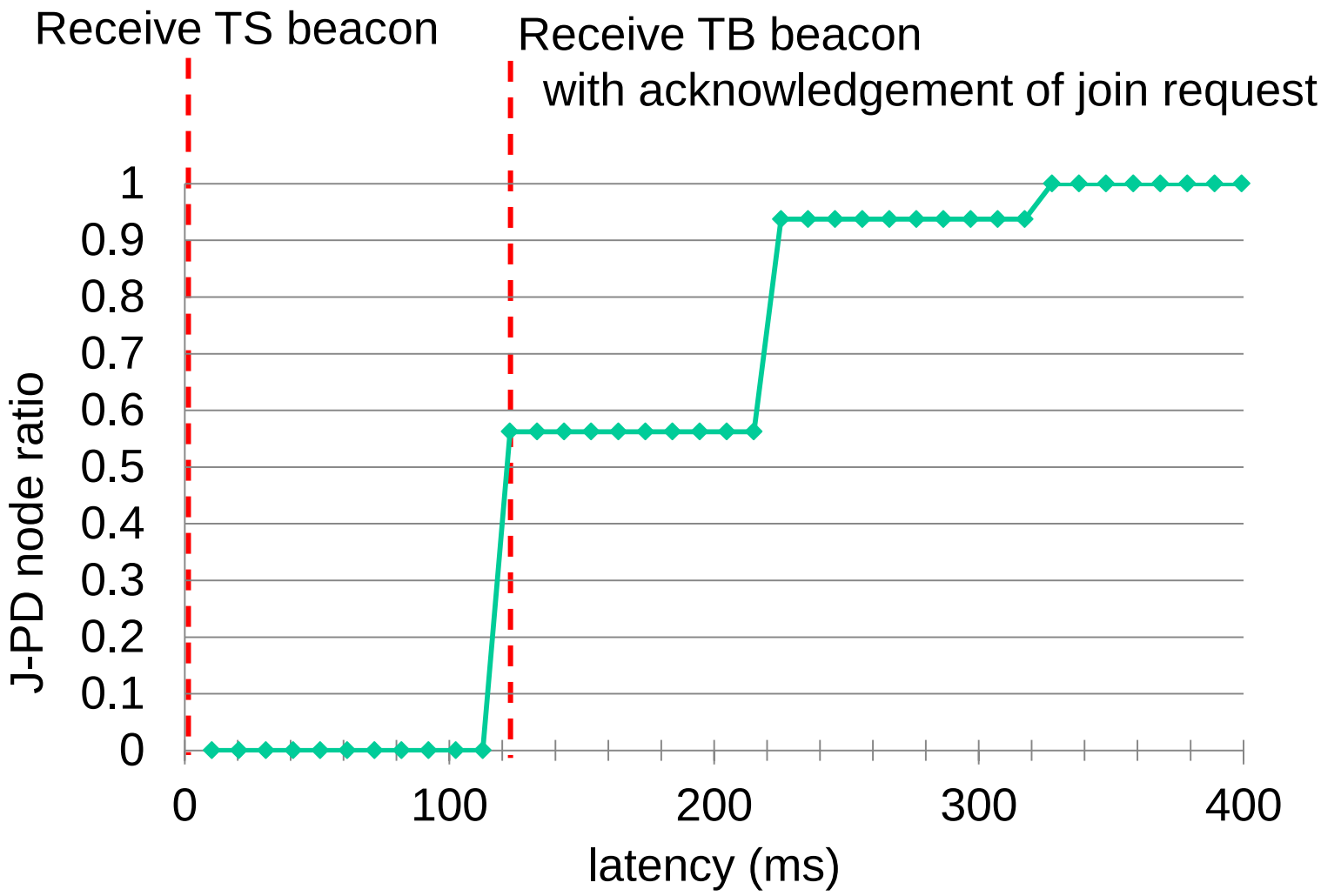
- I-PD Discovered Time
  - Time when a J-PD receives the first TS beacon with its group ID
- J-PD Discovered Time
  - Time at end of TB slot during which J-PD receives first TB beacon that includes its own ID (ie. acknowledgement of join request)
- Association Latency
  - Difference between I-PD Discovered Time and J-PD Discovered Time

Simple Case

Numbers of Nodes and Channels		
# Channels	# I-PD	# J-PD
1	1	64

+ Extra condition:
distance < 50 m so packet loss is only due to collision, not propagation loss

Results of Simple Case



Latency For Various Cases

#ch	# I-PD	# J-PD	Mean Latency (ms)	
			Drop range 50 m	Drop range 100m
1	1	4	108	245
1	1	16	128	258
1	16	16	115	135
1	16	48	115	176
1	32	32	118	137
1	64	64	135	143

Simulation on Group Operation

Group Operation

① Any I-PD that initiated a group will act as a temporary leader of the formed group (***distributed and self-organized control***). Moreover, the role of leader can be changed among PDs in the group.

② Communications within the formed group are undertaken using an selected mode and can move to the other selected modes.

③ Coordination may performed among neighbor groups for channel sharing or interference avoidance.

Operation Procedure

- Broadcast by Initiators (I-PD) to Joiners (J-PD)
- Start broadcasting after receiving first Join Request
- Broadcast as many packets as possible from application-packet-queue during allocated part of CFP (specifically *1/3* part of CFP)
- Full queue condition: Application packets created at rate > maximum transmit rate determined by packet-size/CFP duration.
- Measure application traffic flow in last *200 milliseconds* of simulation

Parameters Examined

- Packet Delivery Ratio (PDR)
  - Ratio of the number received by a J-PD to the number of application data packets sent by an I-PD, averaged over all J-PD
- Goodput
  - Total number of packets received by all J-PD during 200 milliseconds, expressed as bytes per second per square-meter. Computed as number-of-packets x (512 bytes) / (0.2 sec x 500 m x 500 m) = number-of-packets x 0.01024 bytes per second per square-meter
- Fairness
  - Jain's index for number of packets received by J-PDs

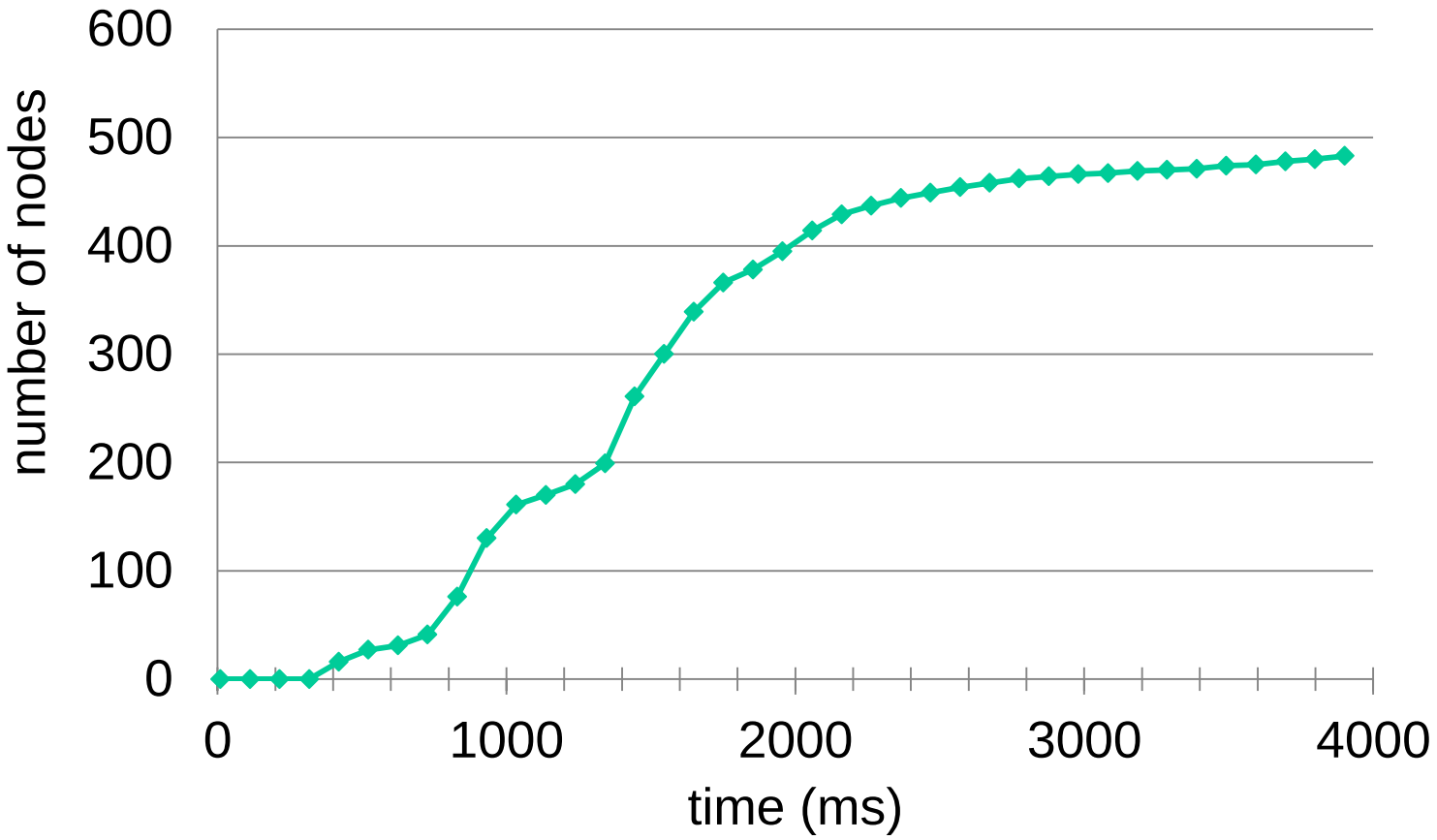
Moderate Density Case

Numbers of Nodes and Channels		
# Channels	# I-PD	# J-PD
16	32	512

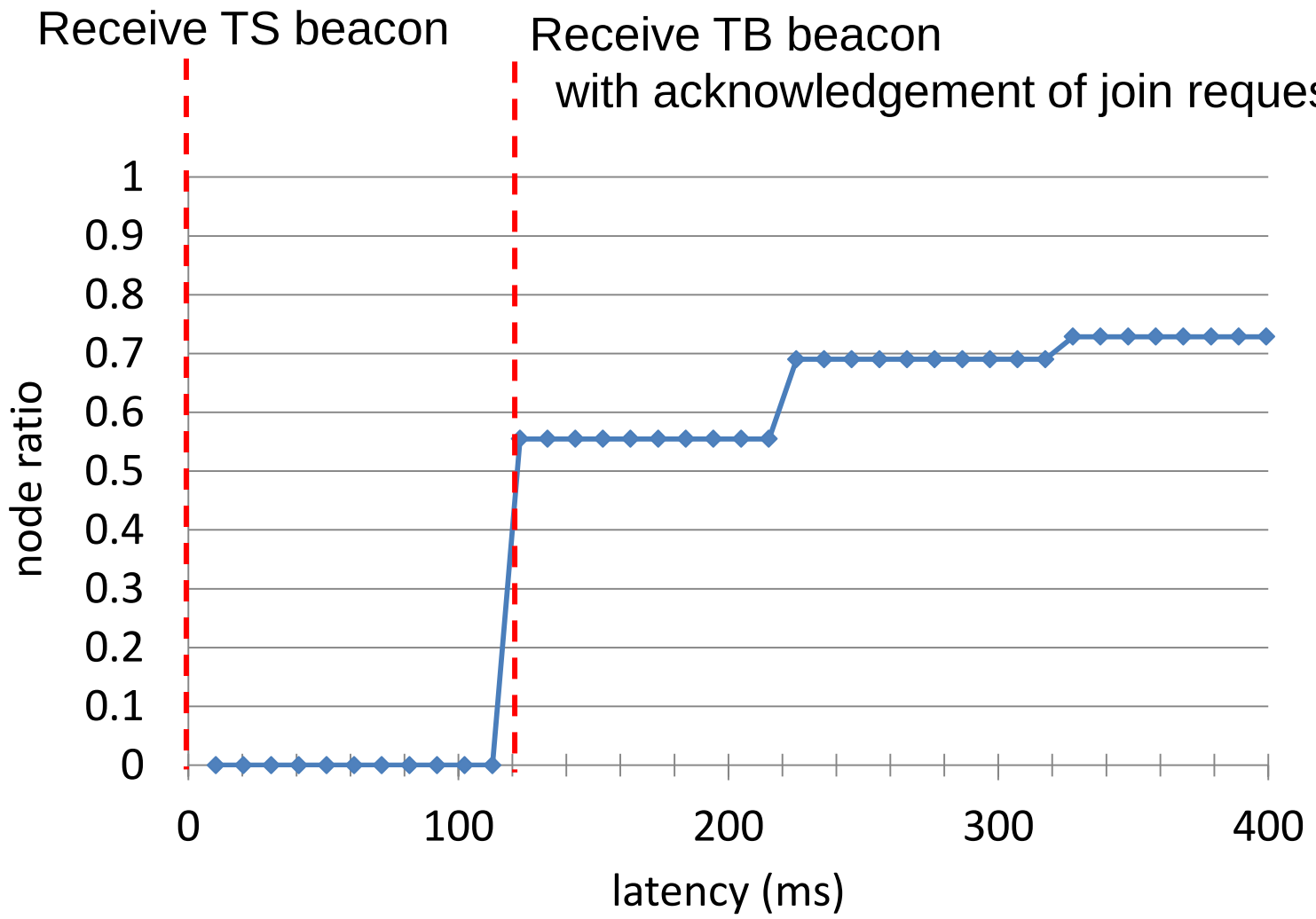
Results At A Glance

Association			Operation		Combined
# Joined	Join Ratio	Mean Latency [ms]	PDR	Jain's Index	Power [mWs]
485	0.95	331	0.91	0.78	29

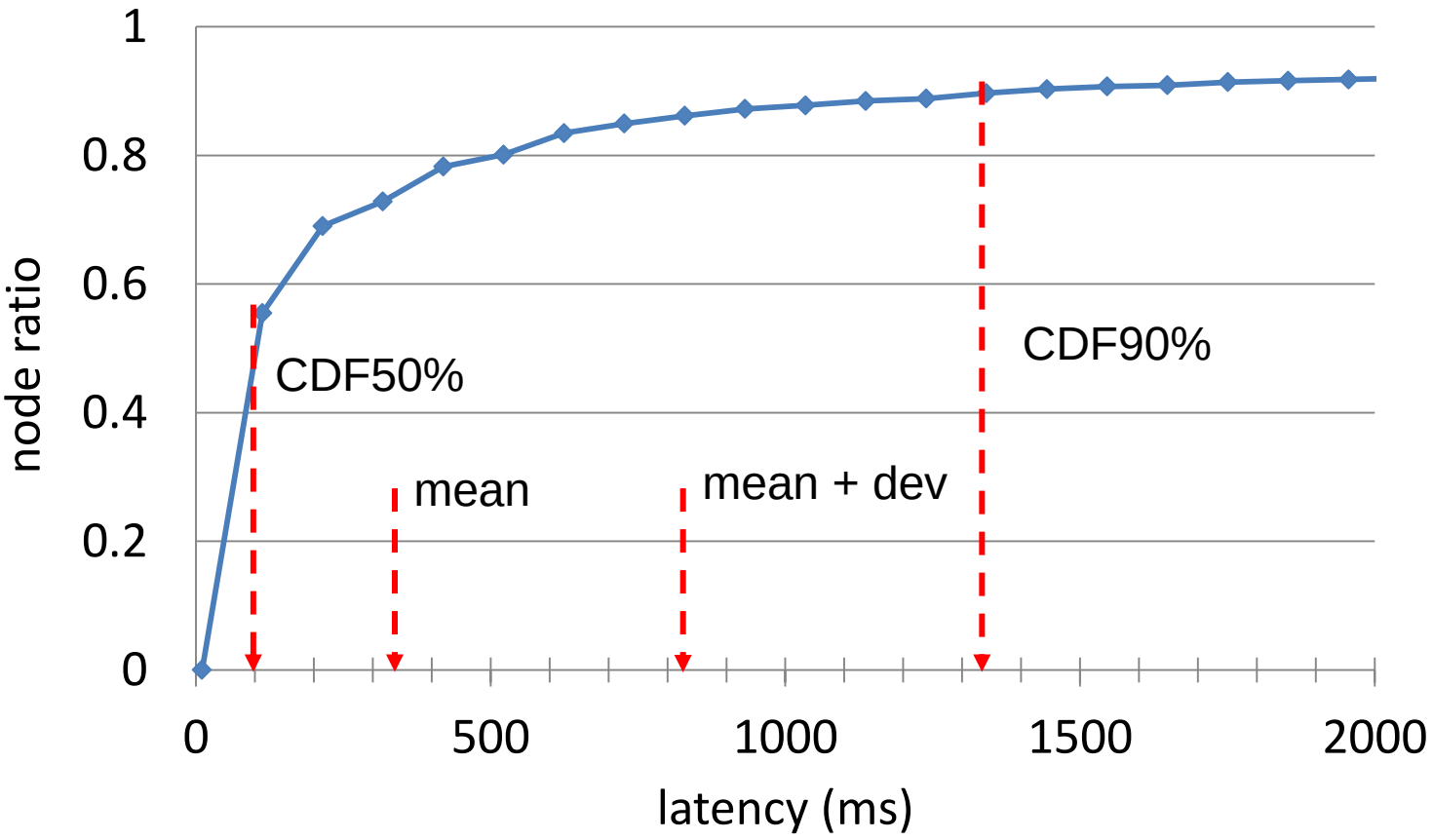
Associated J-PD By All I-PD



Results of Association Latency (short-time)



Results of Association Latency (long-time)



Performance For Various Parameters

# ch	# node	# I-PD	# J-PD	Ratio I/ch	Ratio J/I	Associated		Mean Latency [ms]	PDR	Jain's Index	Power [mWs]
						#	Radio				
16	48	16	32	1	2	32	1	355	0.83	0.69	36
16	544	32	512	2	16	485	0.94	331	0.91	0.78	29
16	1056	32	1024	2	32	991	0.97	345	0.85	0.74	32
16	576	64	512	4	8	486	0.94	301	0.9	0.75	32
16	1088	64	1024	4	16	965	0.96	319	0.90	0.73	31
16	1152	128	1024	8	8	970	0.95	325	0.9	0.74	31

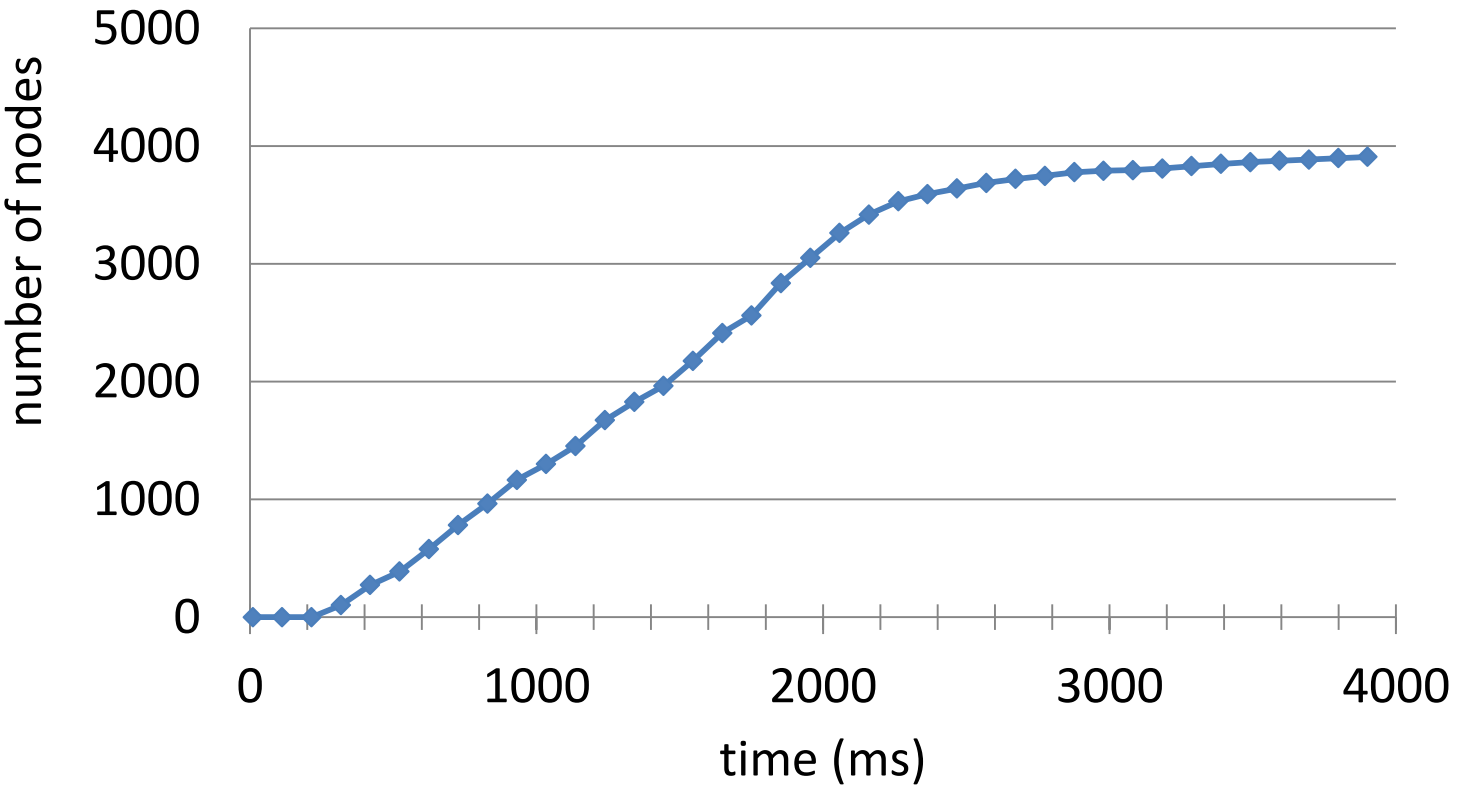
High Density Case

Numbers of Nodes and Channels		
# Channels	# I-PD	# J-PD
16	256	4096

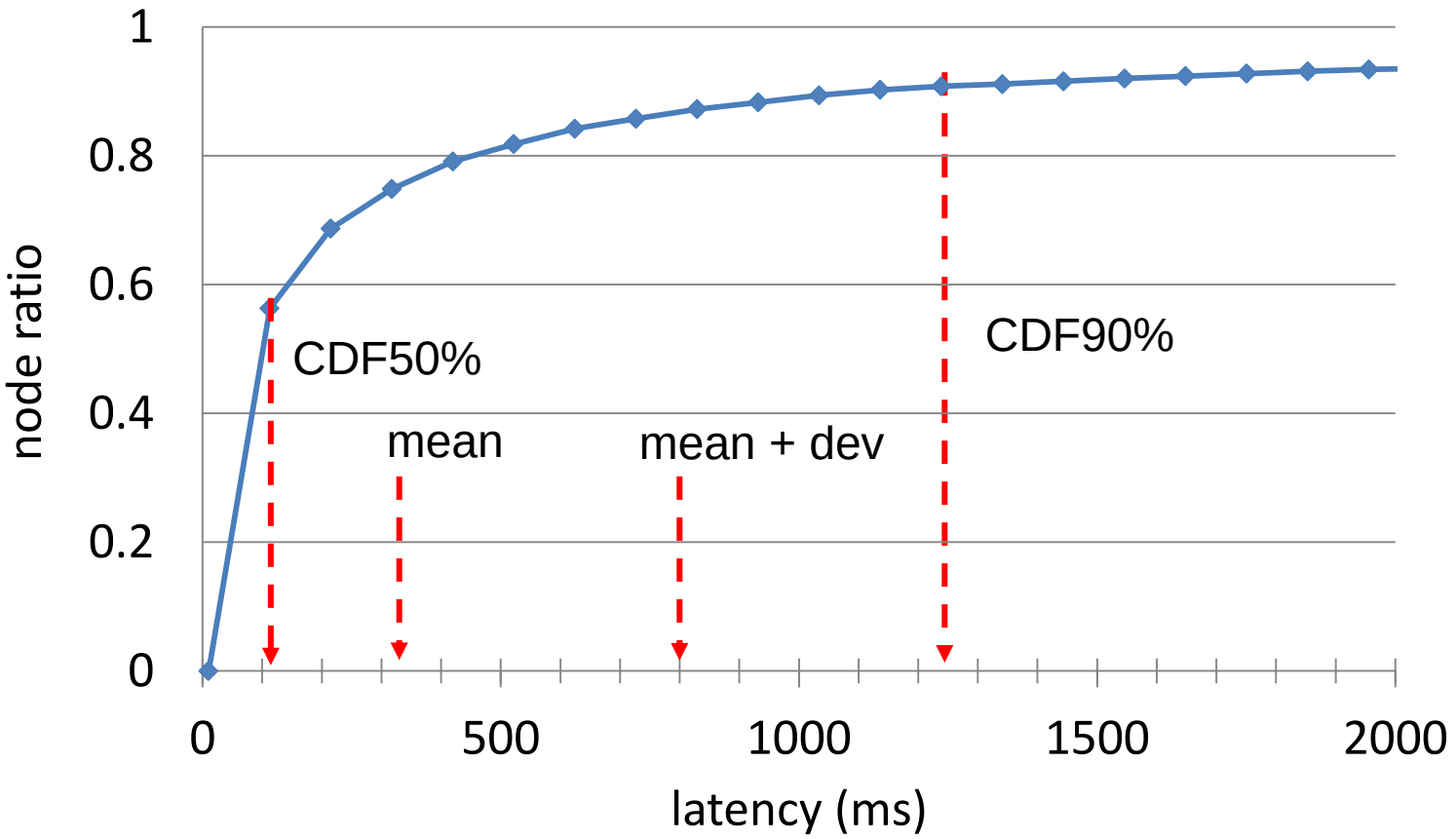
Results At A Glance

Association			
# Associated	Associated Ratio	Mean Latency [ms]	Power [mWs]
3917	0.96	327	46

Associated J-PD By All I-PD



Results of Association Latency



Conclusions

- Simulation results based on NICT's MAC proposal are presented for
  - Discovery
  - Association
  - Group operation