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

Submission Title: [NICT's MAC Proposal With Simulation Results]
Date Submitted: [July 07 2013]
Source: [Huan-Bang Li, Marco Hernandez, Igor Dotlic, and Ryu Miura] Company [NICT]
Address [3-4 Hikarino-oka, Yokosuka, Kanagawa, Japan]
Voice:[+81 468475104], FAX: [:[+81 468475431], E-Mail:[lee@nict.go.jp]

Re: [Response to call for proposal of 15.8 PAC

Abstract: [MAC proposal for IEEE802.15.8 with simulation results]

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

NICT's MAC Proposal With Simulation Results

Huan-Bang Li
Marco Hernandez
Igor Dotlic
Ryu Miura

National Institute of Information and Communications Technology (NICT), Japan

Purpose of This Document

- Performance evaluation of NICT's MAC proposal 15-13-0270-01-0008.

Features

- A PD can operate at one common mode and several operation modes that are allocated in a PAC frequency band.
- The common mode shall be assigned with a fixed RF channel, and shall be defined by fixed PHY parameters including modulation, FEC, and data rate.
- An operation mode should operate at one of the RF channels. PHY parameters, including modulation, FEC, and data rate, can be selected from PHY specifications.

Basic Operations

- Initiator 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
- Joiner 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

Acronyms

#: “Number of”

Ch: channels

I-PD: Initiator PD

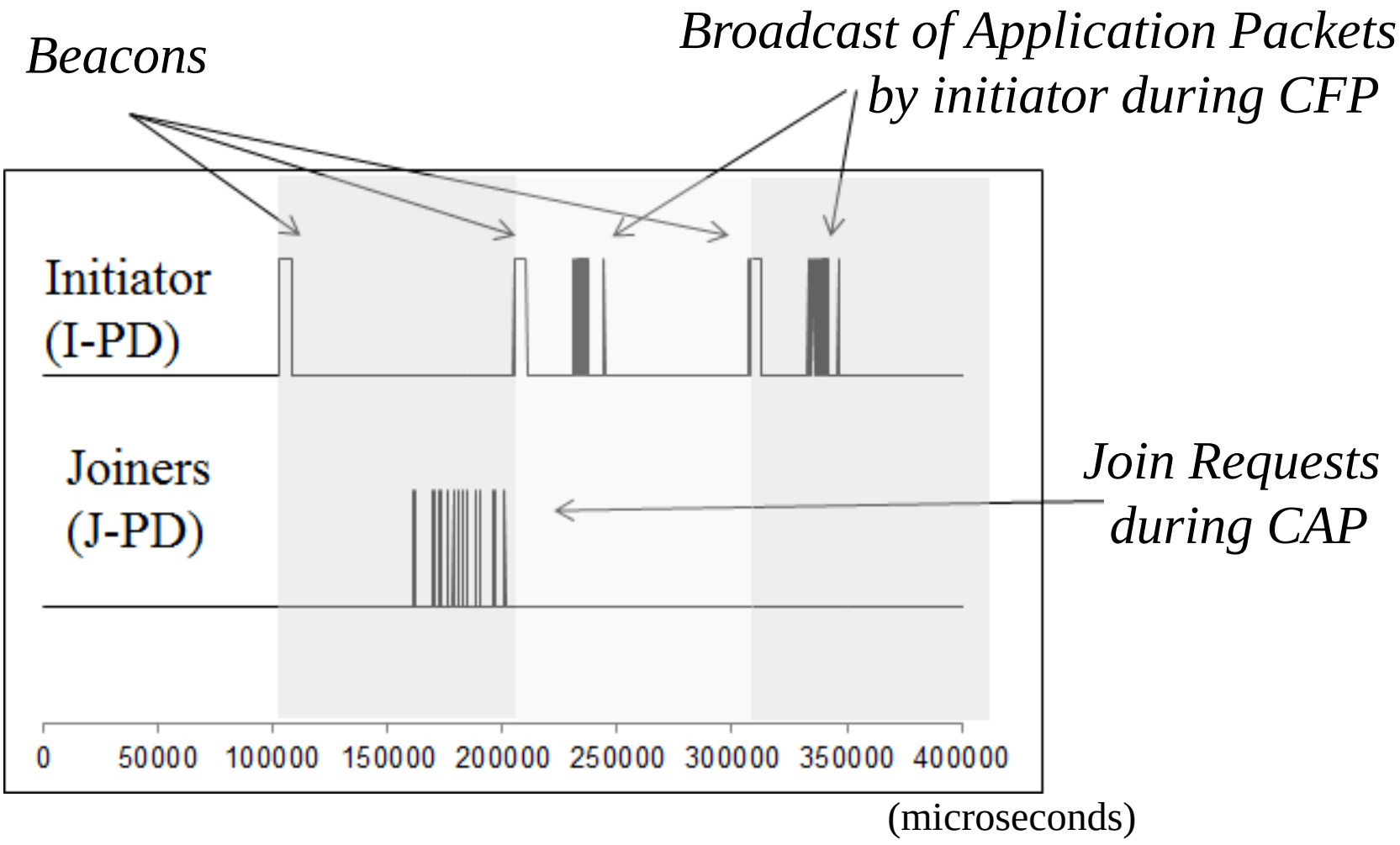
J-PD: Joiner PD

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

Simulated Transmission Behavior



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

PHY Parameters Used In Simulations

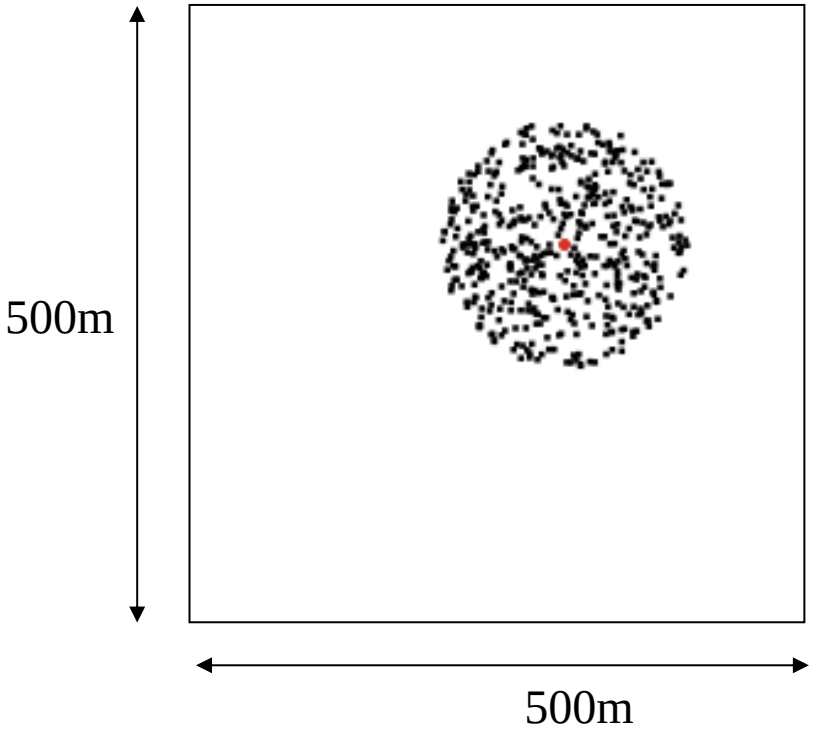
Parameter	Value
PHY	BPSK(1/2)
Symbol rate	1 MHz
Data rate	0.5 Mbps
Bandwidth	2MHz
Number of channels (@2.45 GHz)	16 (5MHz Spacing)
TX Power	20dBm
Carrier-Sense threshold	-109.5 dBm
Channel loss (below rooftop, 2.45GHz)	DCN-0459-08, p. 16
Es/N0 : BER table	DCN-0058-01
Power Consumption (@3.6V)	Tx: 11.3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

Large Scale Simulation Scenario

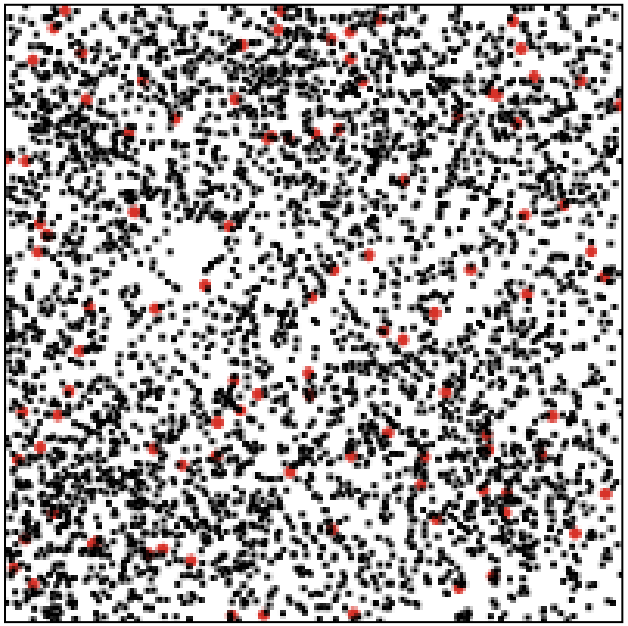
- Layout
  - 500m x 500m
  - 2-stage drop, with 100m spread range for each drop
  - Static Mobility
- Initiator “turn on”
  - at random times during an initial “dispersion” time (to avoid extreme case of all starting at the same time)
- Simulation time
  - 4 seconds, corresponding to ~ 40 periods

Layout Examples

Example 1:
1 Initiator and 500 Joiners dropped within 100m radius

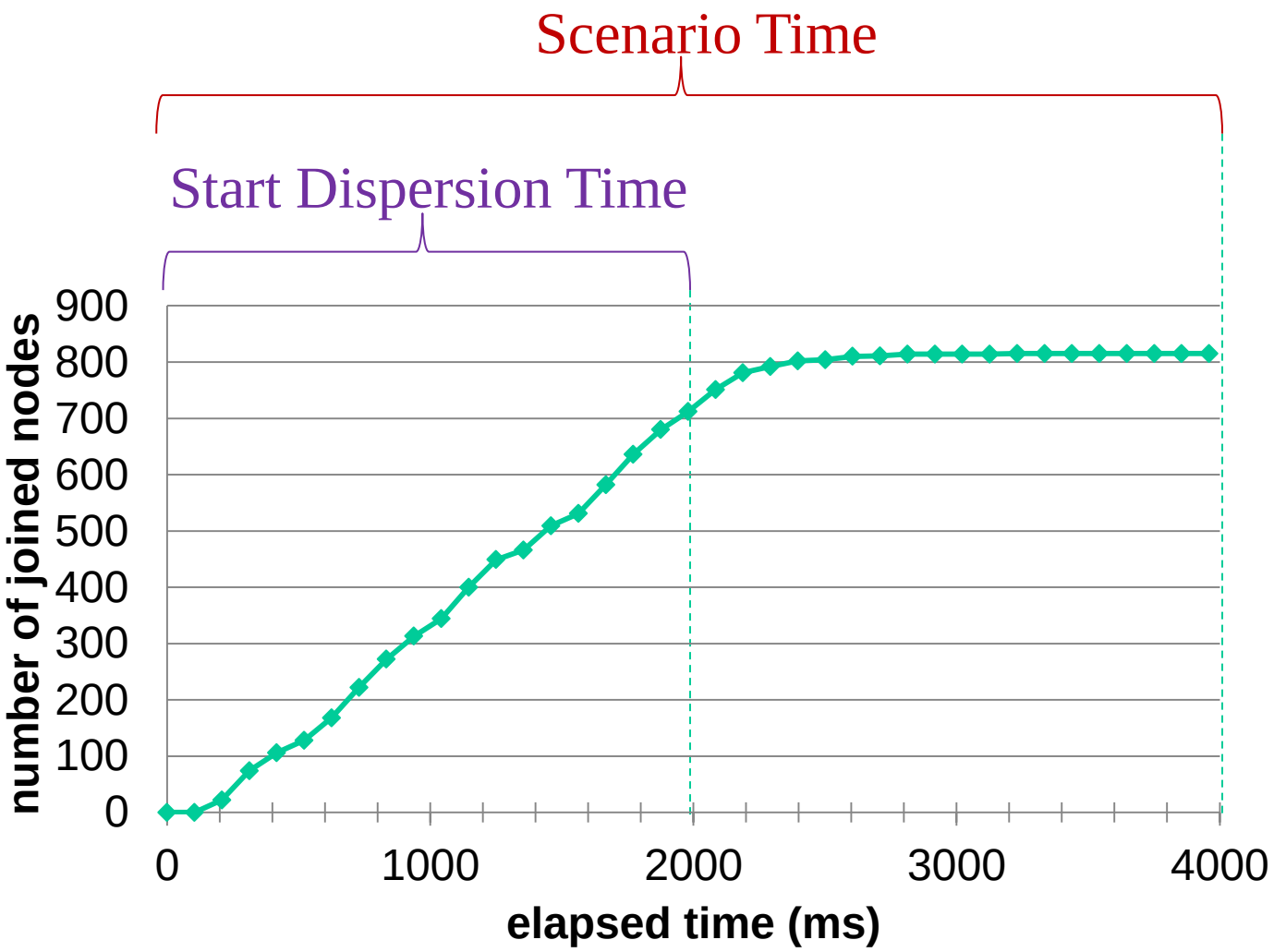


Example 2:
100 Initiator and 4000 Joiners dropped within the whole area.



Red: I-PD. Black: J-PD.

Simulation Scenario



Discovery Latency

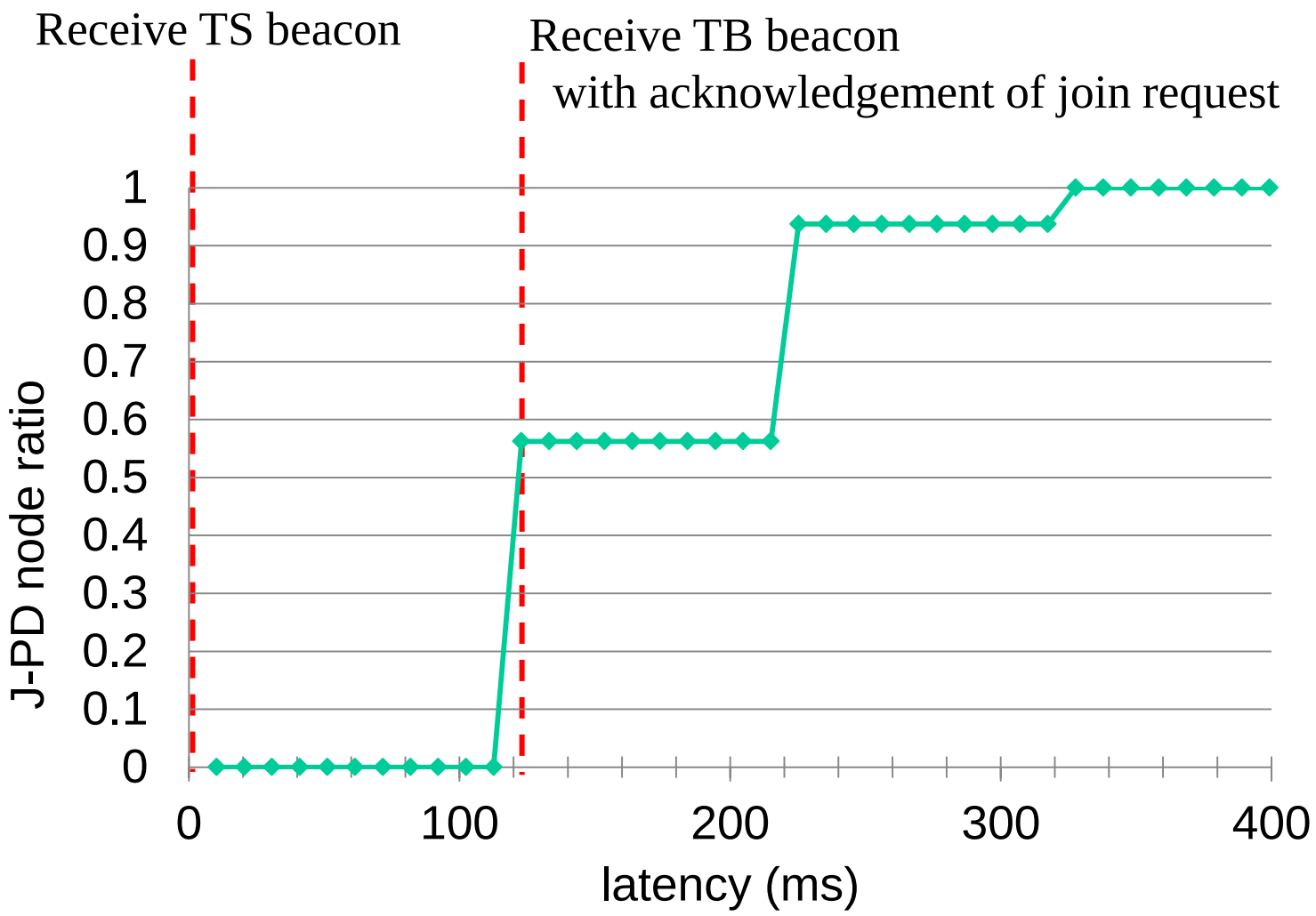
- I-PD Discovered Time
  - Time when a J-PD receives the first TS beacon with its group ID
- J-PD Discovered Time
  - Time at end of TB slot during which J-PD receives first TB beacon that includes its own ID (ie. acknowledgement of join request)
- Discovery Latency
  - Difference between I-PD Discovered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

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

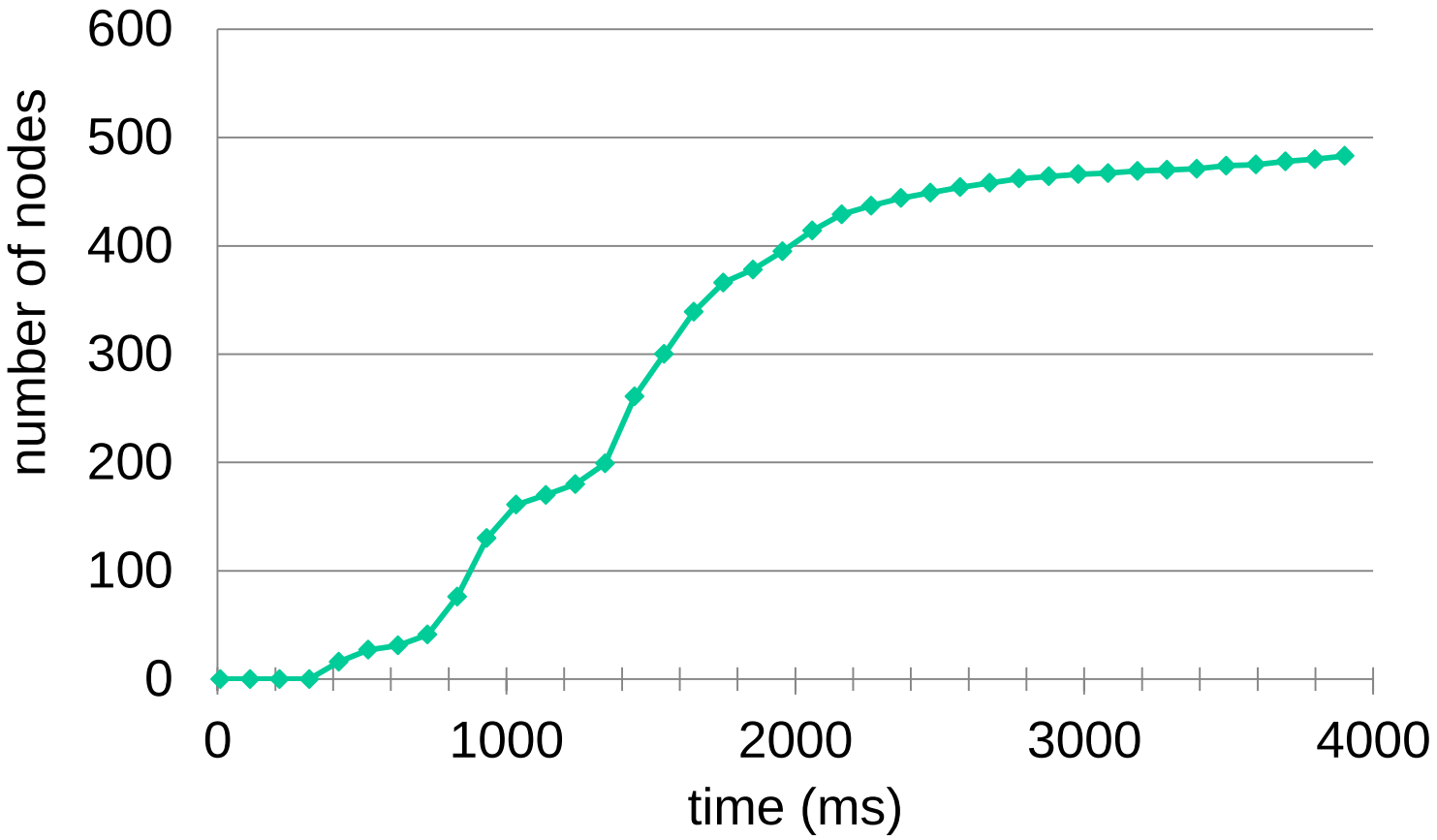
Moderate Density Case

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

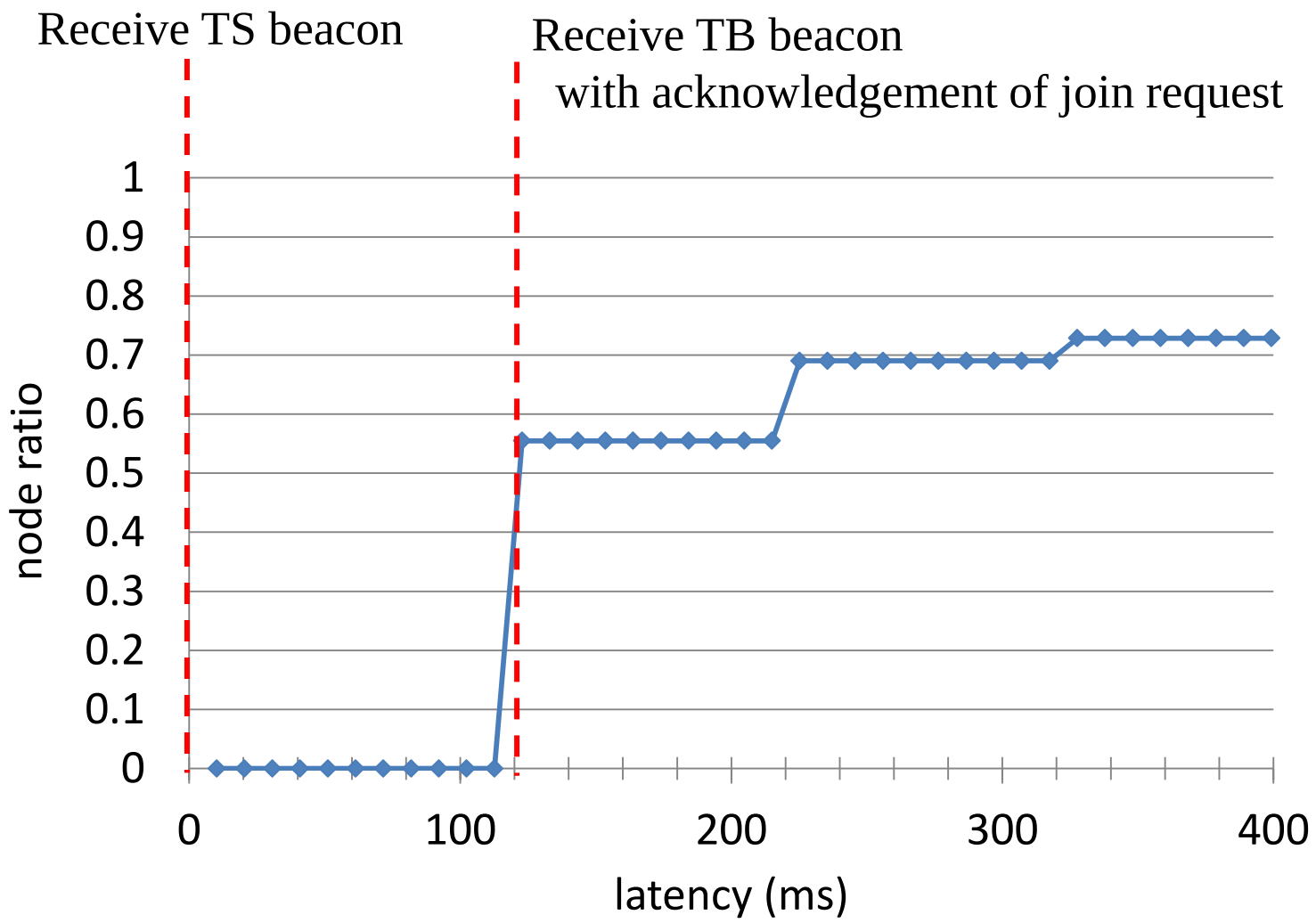
Results At A Glance

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

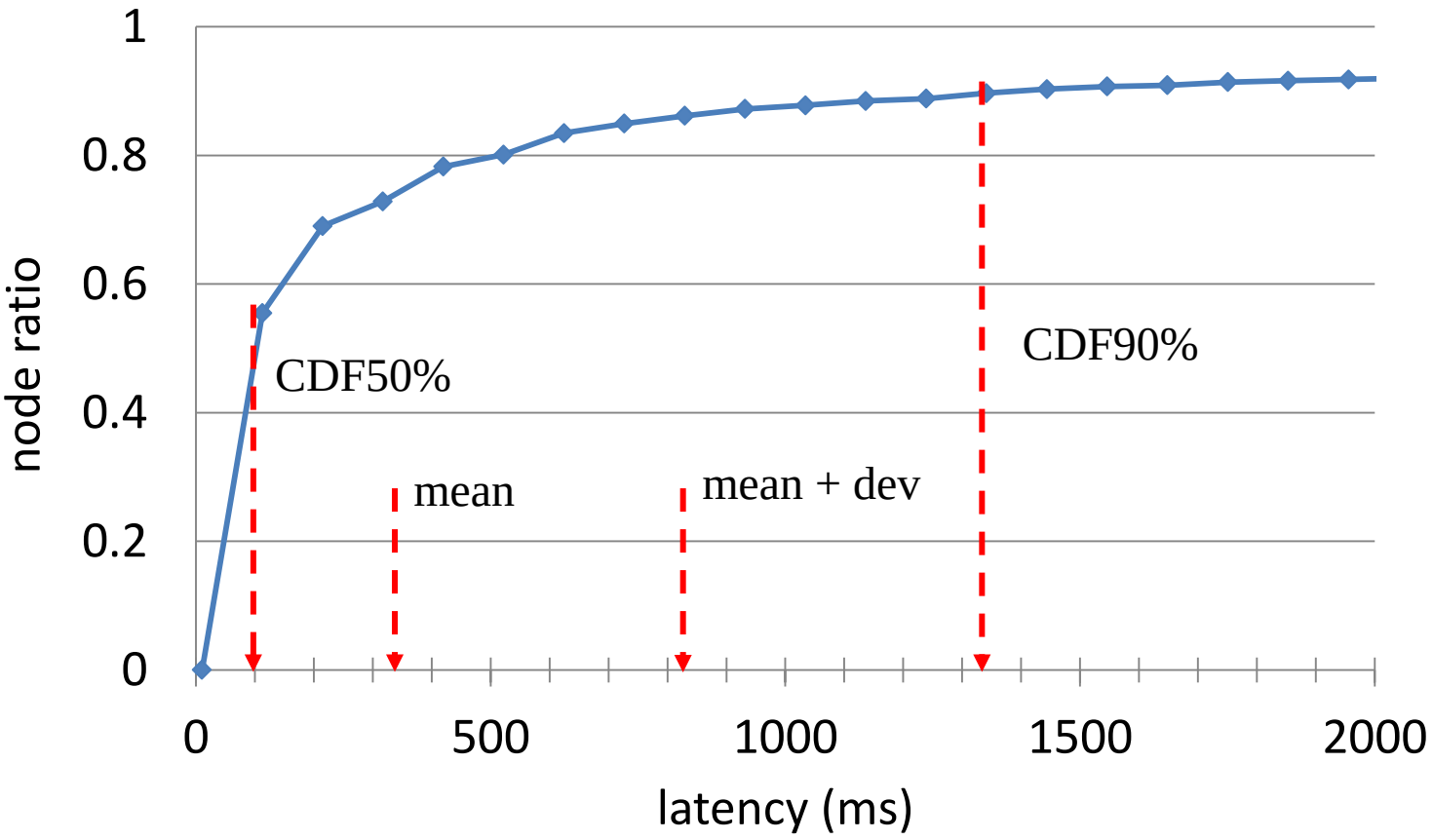
Discovered J-PD By All I-PD



Results of Discovery Latency (short-time)



Results of Discovery Latency (long-time)



Effects of Superframe Length

Numbers of Nodes and Channels		
# Channels	# I-PD	# J-PD
16	32	1024

Parameters					Performance		
Period [usec]	Structure Ratio	TB [usec]	CFP [usec]	CAP [usec]	Mean Latency [msec]	# J-PD Joined (Join Ratio)	Energy [mWsec]
51200	10:20:20	10240	20480	20480	221	1003 (0.98)	57
102400	10:45:45	10240	46080	46080	341	991 (0.97)	32
204800	10:90:90	10240	92160	92160	512	931 (0.91)	31

Note: Size of TB is kept constant.

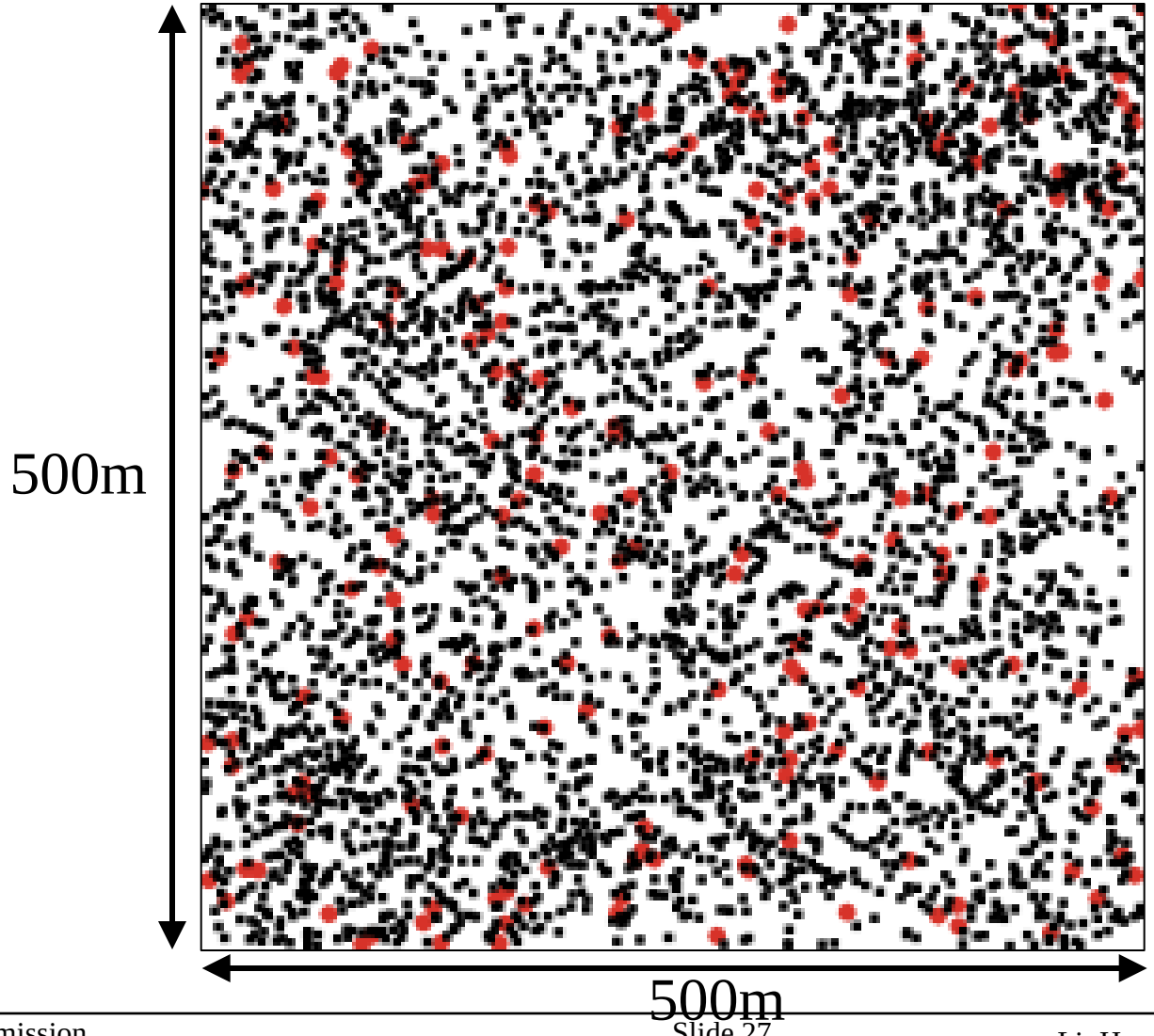
Performance For Various Parameters

# ch	# node	# I-PD	# J-PD	Ratio I/ch	Ratio J/I	# Joined	Join Ratio	Mean Latency [ms]	PDR	Jain's Index	Power [mWs]
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

Layout

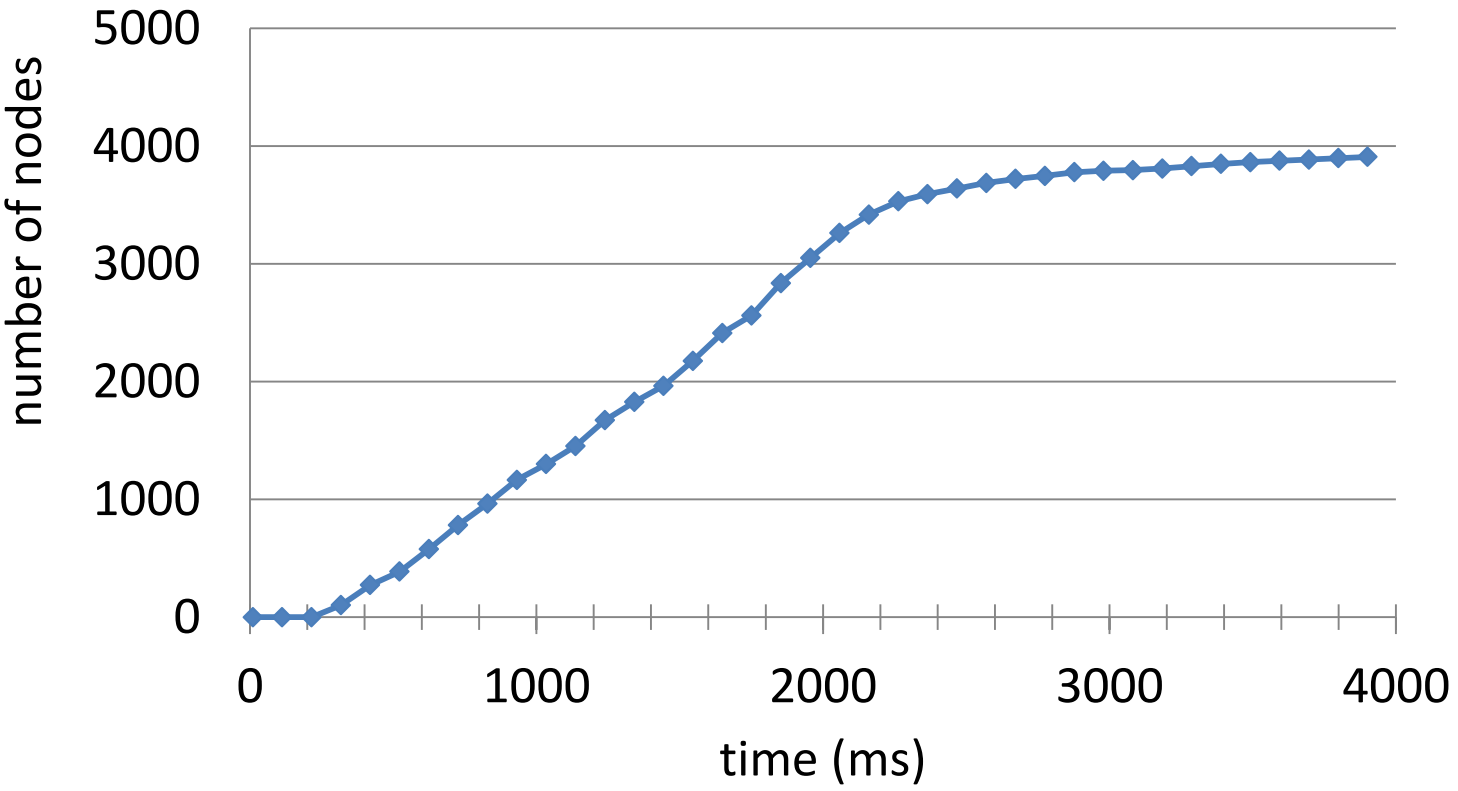


Red: I-PD
Black: J-PD

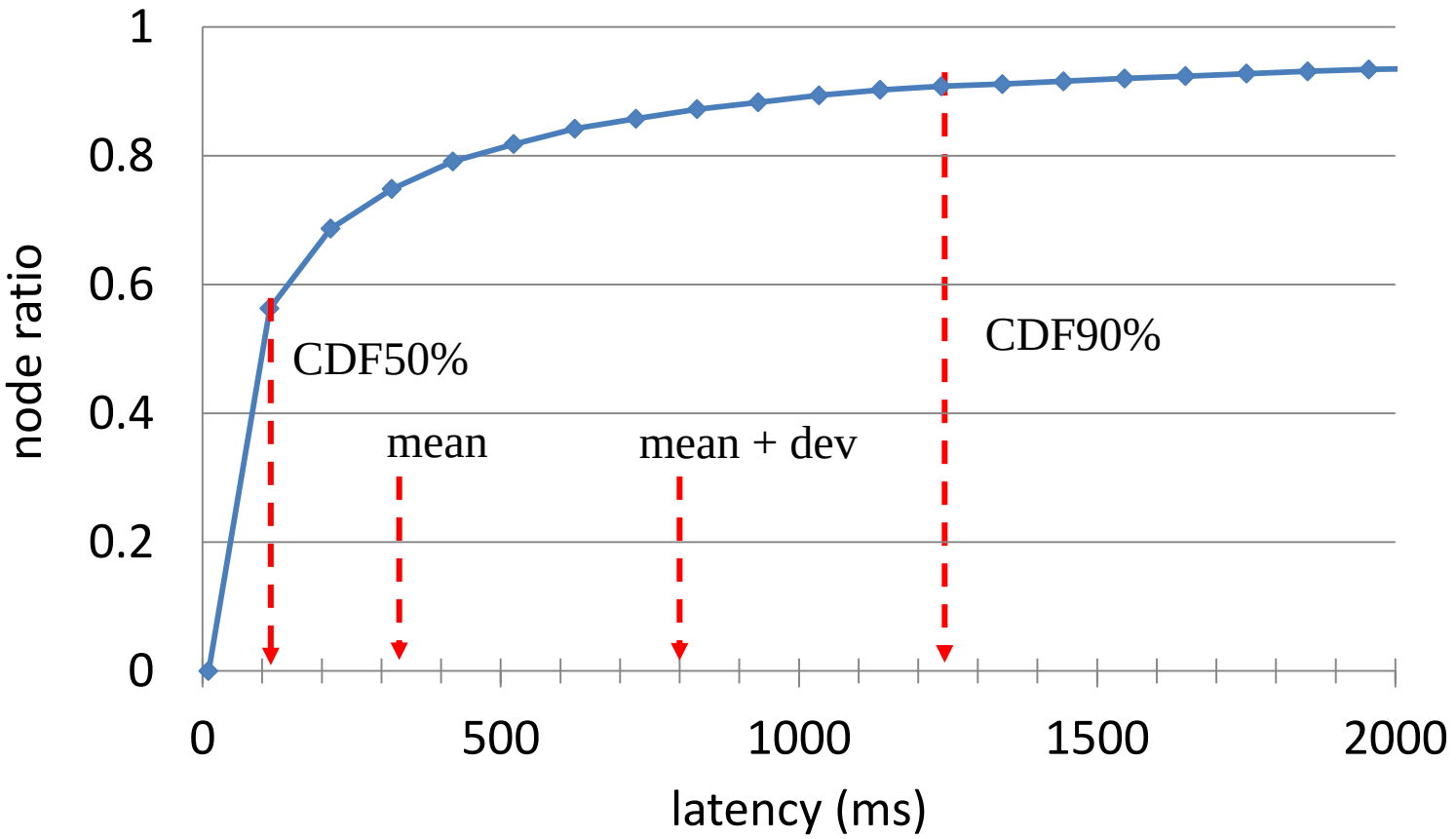
Results At A Glance

Discovery			
# Joined	Join Ratio	Mean Latency [ms]	Power [mWs]
3917	0.96	327	46

Discovered J-PD By All I-PD



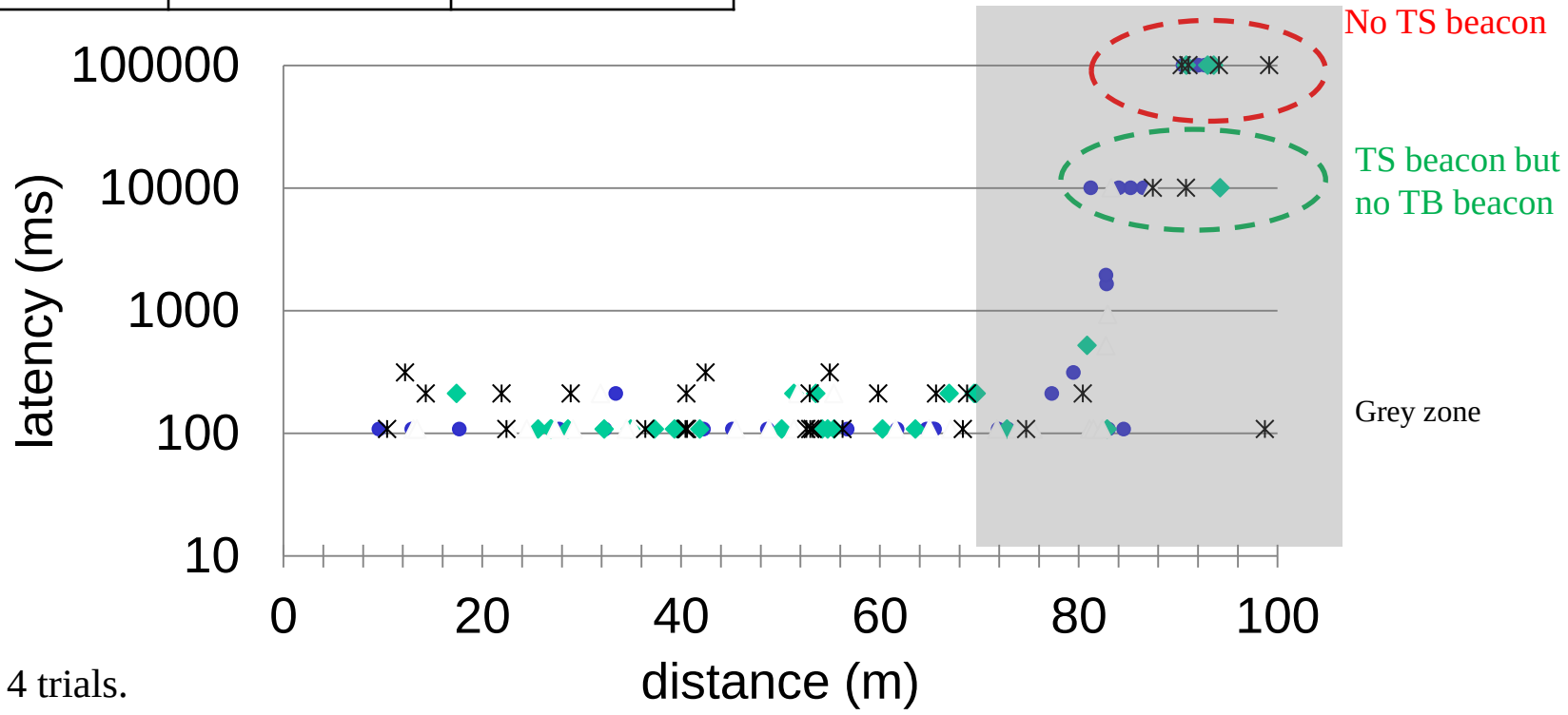
Results of Discovery Latency



Latency versus Distance of J-PD from I-PD

Numbers of Nodes and Channels		
# Channels	# I-PD	# J-PD
1	1	32

TS beacon receive threshold: -109.5 dBm
Mean Latency=189 ms (Deviation 259 ms)



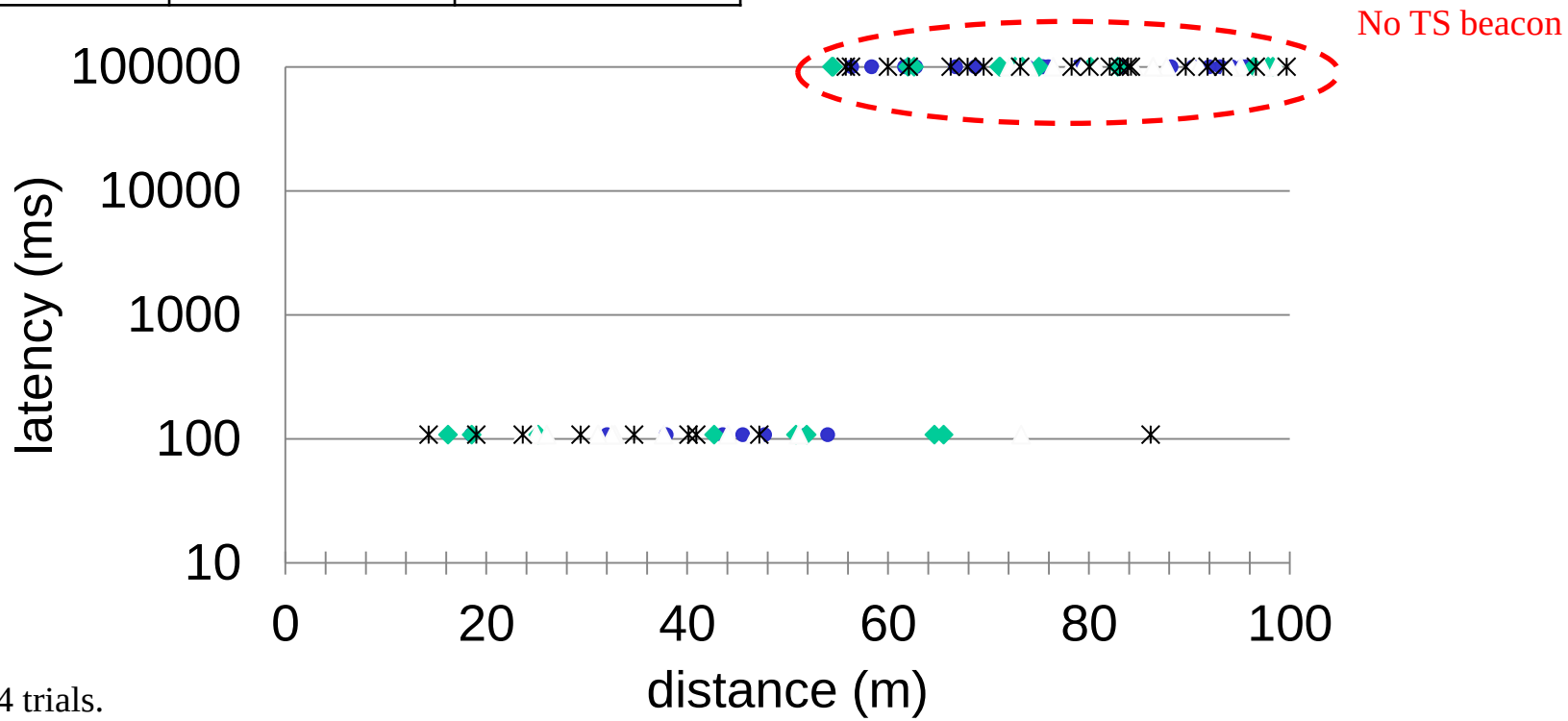
Results of 4 trials.
10000ms assigned to nodes that have received TS beacon but no TB beacon,
100000ms are assigned to nodes that have not received TS beacon.

Latency versus Distance of J-PD from I-PD

Numbers of Nodes and Channels		
# Channels	# I-PD	# J-PD
1	1	32

TS beacon receive threshold: -76 dBm

Mean Latency=108.2 ms (Deviation 0.1 ms)



Results for 4 trials.

10000ms assigned to nodes that have received TS beacon but no TB beacon,

100000ms are assigned to nodes that have not received TS beacon.

Conclusion Remarks

- Simulation results of NICT's MAC proposals for 15.8. are summarized.
- When limiting the ratio of J-PD (number of J-PD that join into a single group), most of the discovery could be completed within a superframe period.
- When limiting the range of J-PD from the I-PD, most of the discovery could be completed within a superframe period.
- High capacity to contain J-PDs (less effect by the number of J-PD)

Backup Slides

Definition of Superframe Length

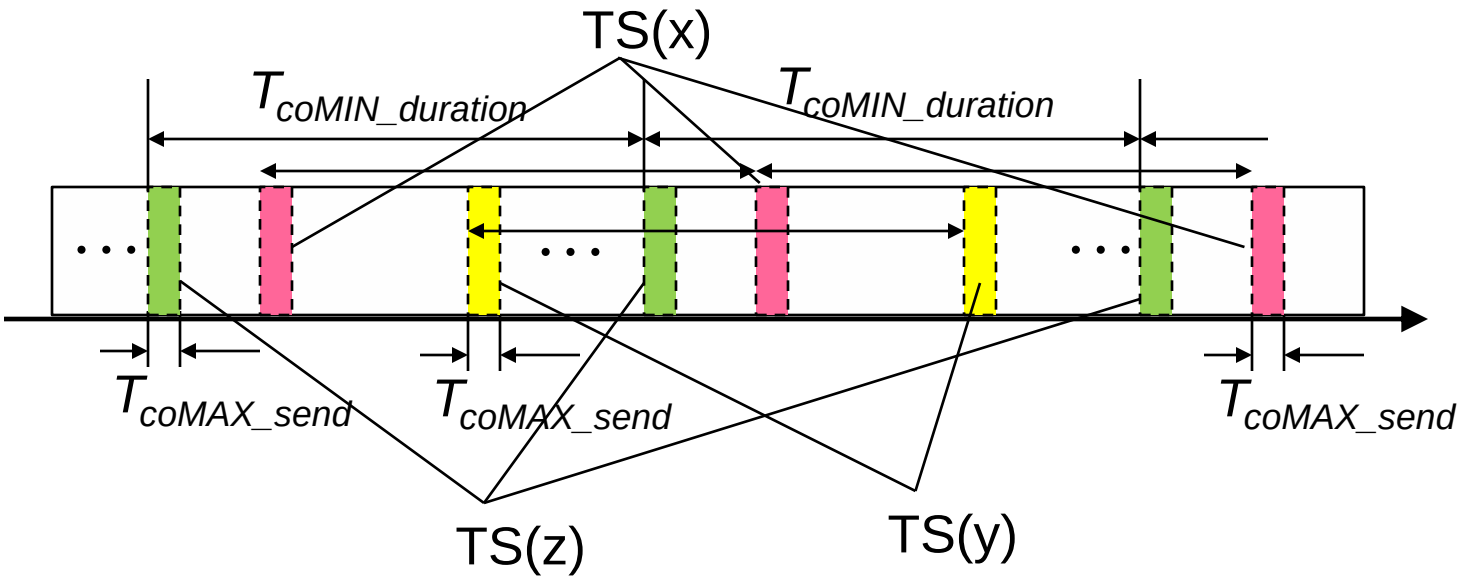
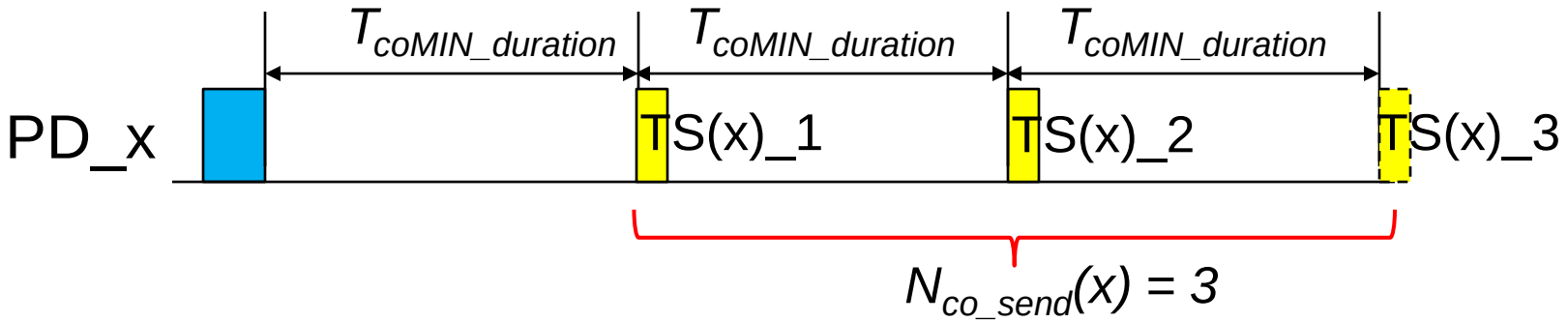
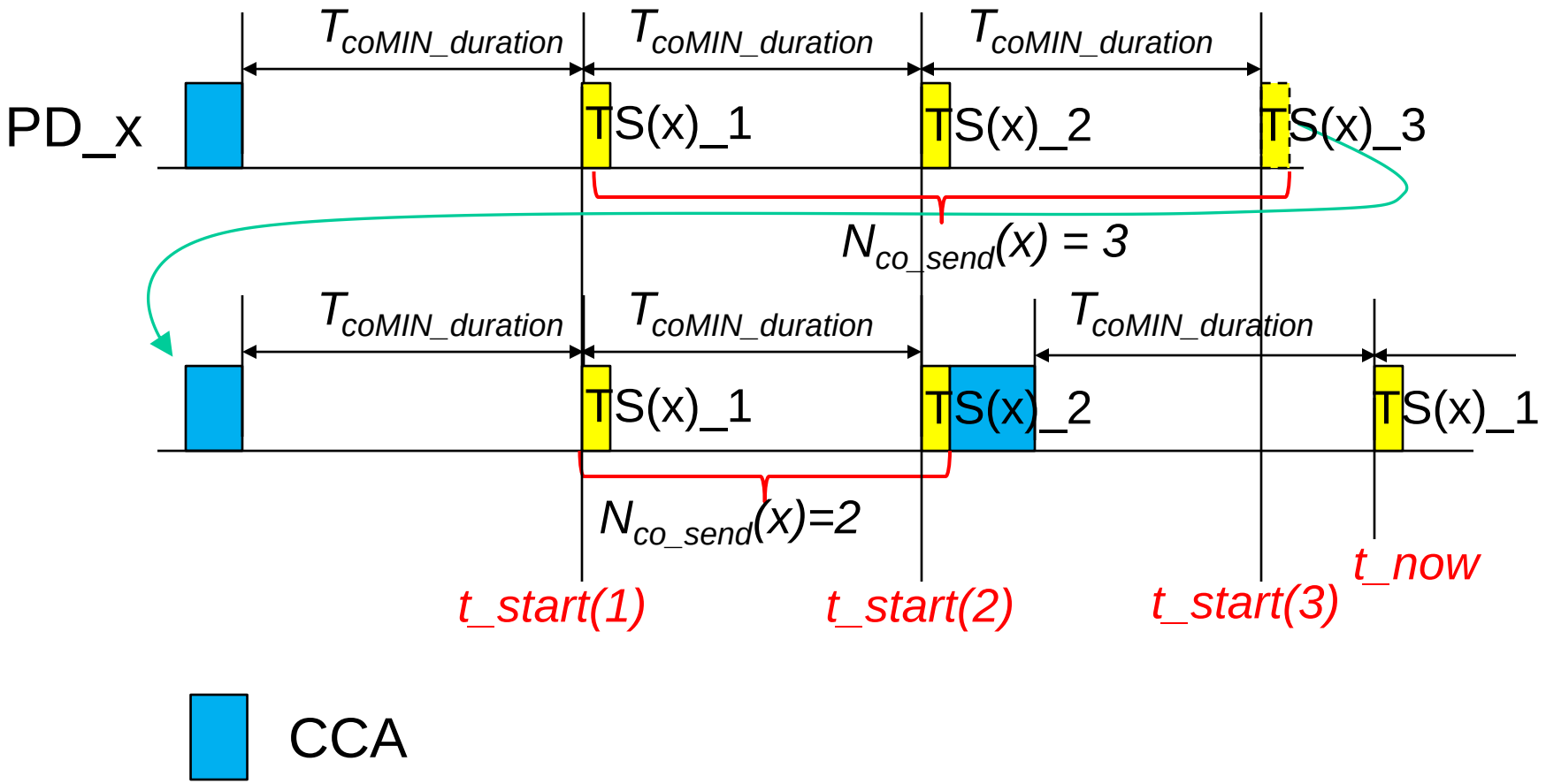


Illustration of Constraint 3 A)

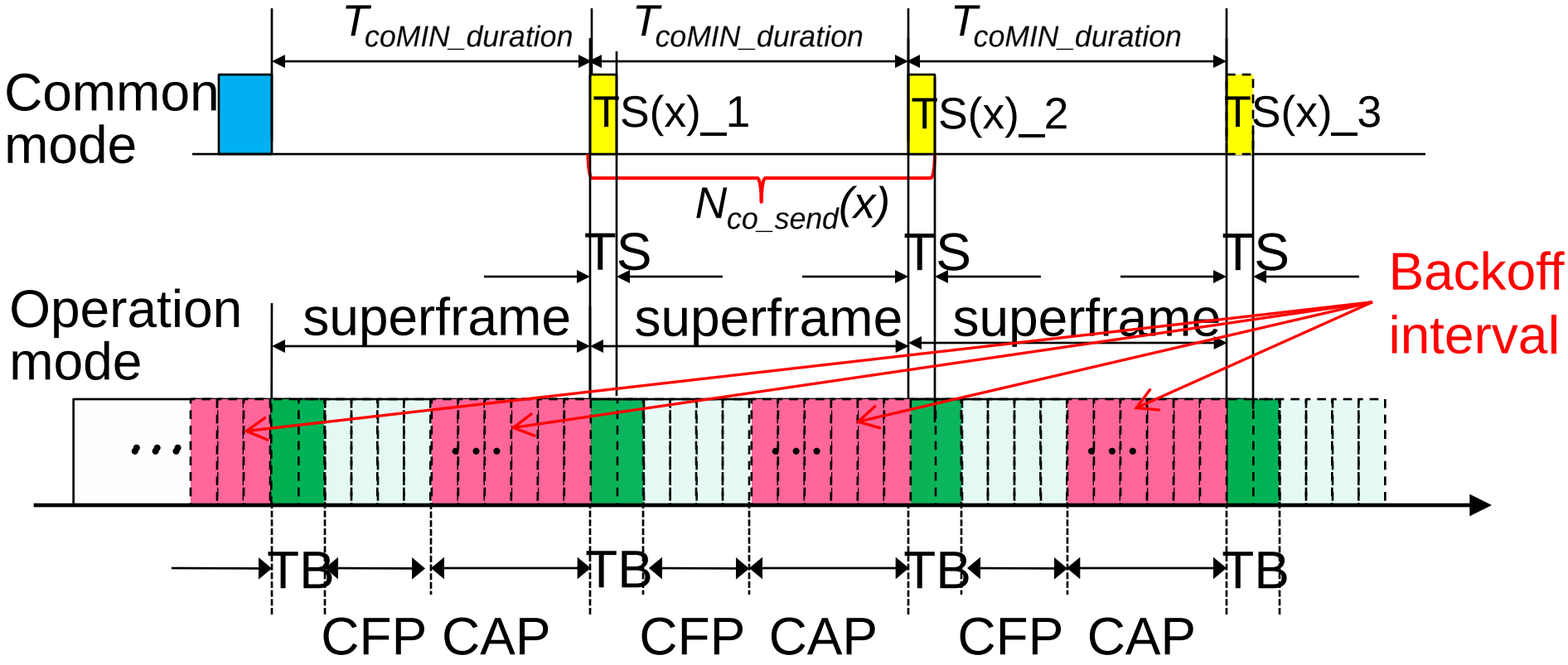


CCA

Re-Broadcasting of TS



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.