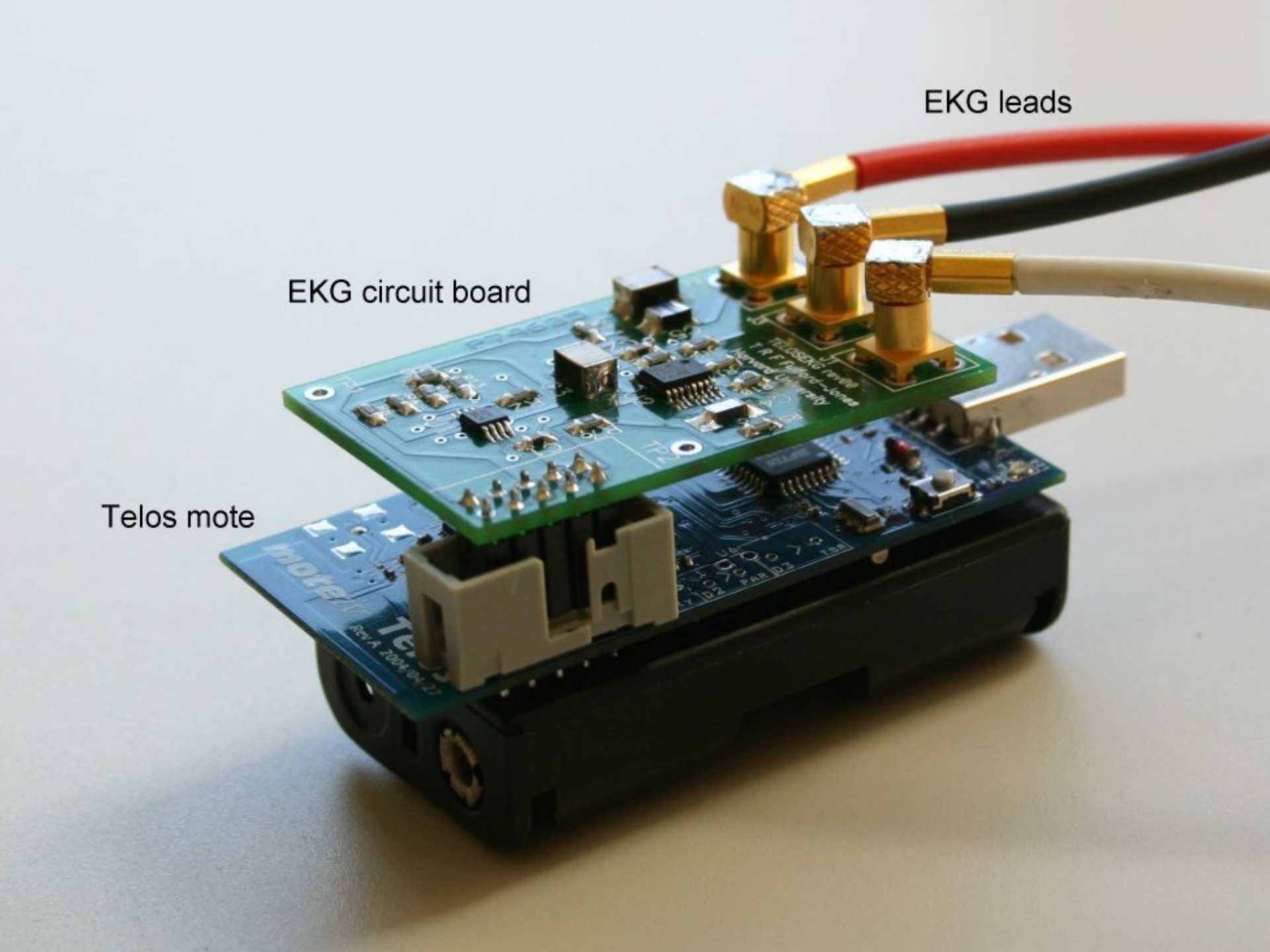
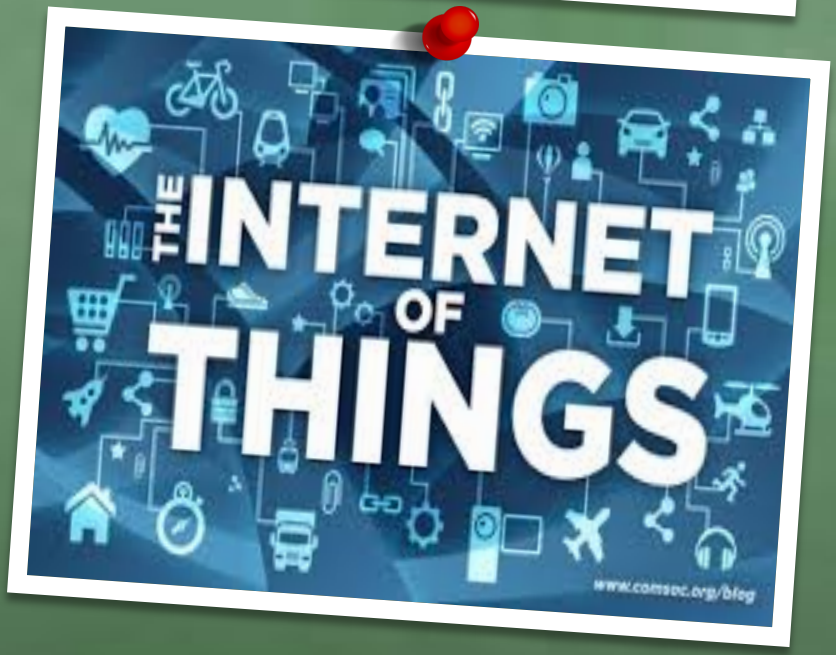
Splash: Fast Data Dissemination with Constructive Interference in Wireless Sensor Networks

Manjunath Doddavenkatappa, Chan Mun Choon and Ben Leong
National University of Singapore


EKG leads
EKG circuit board
Telos mote


THE INTERNET OF THINGS
www.comsec.org/blog

A Fundamental Service: Data/Program Dissemination

A dissemination protocol is required throughout the life of a sensor application

Dissemination *completion time* is critical

Completion time for existing protocols is still in the order of minutes

Culprit is Contention Resolution

SPLASH

Eliminate the need for contention

Constructive Interference
[Glossy'2011]

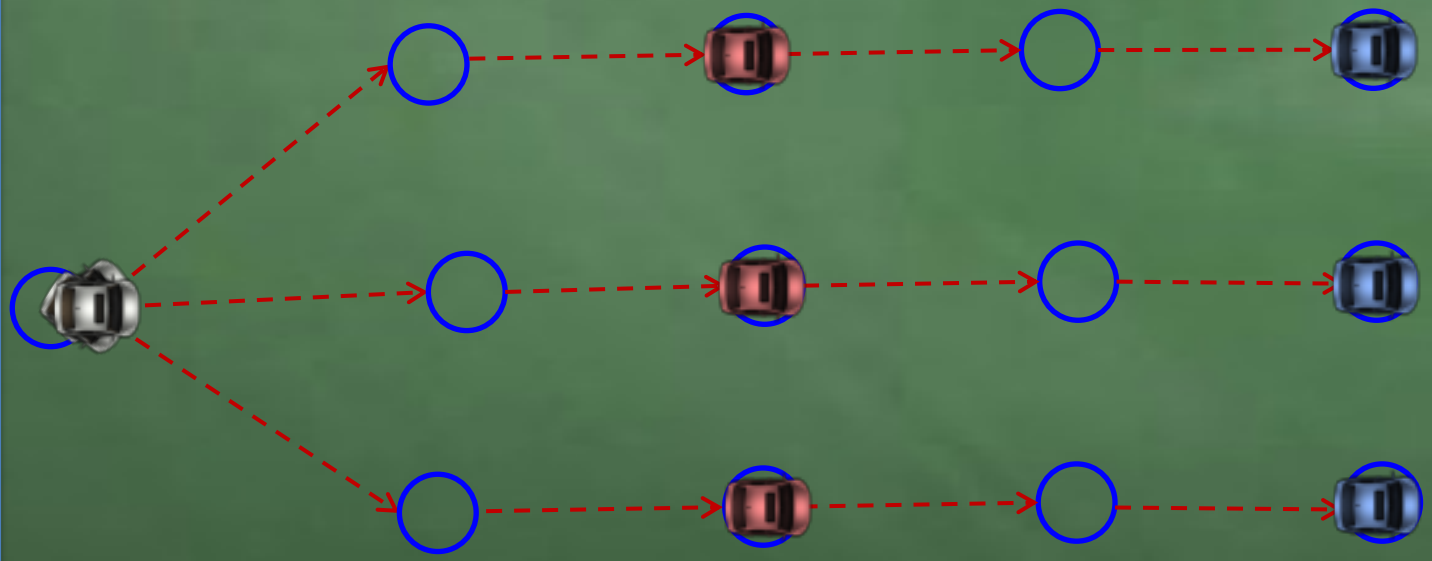
Channel Diversity
[PIP'2010]

SPLASH

Eliminate the need for contention

Constructive Interference
[Glossy'2011]

Channel Diversity
[PIP'2010]



Press escape to exit animation and then move on to the next slide

SPLASH

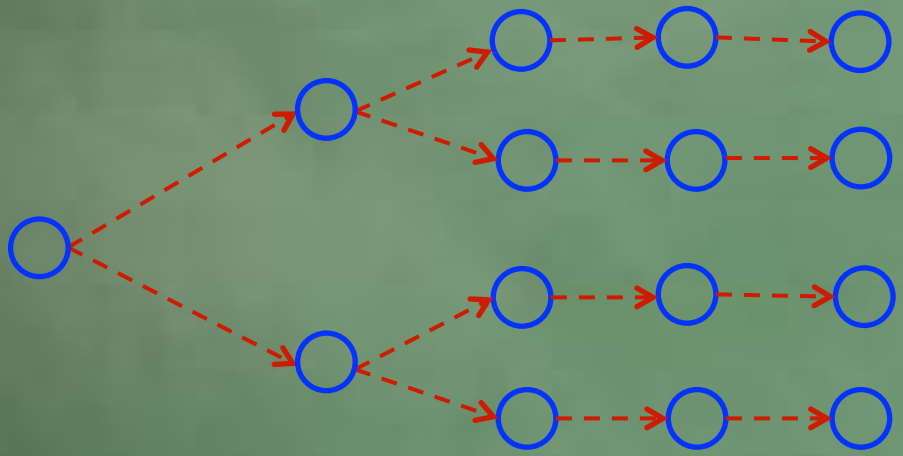
Transmission
Density
Diversity

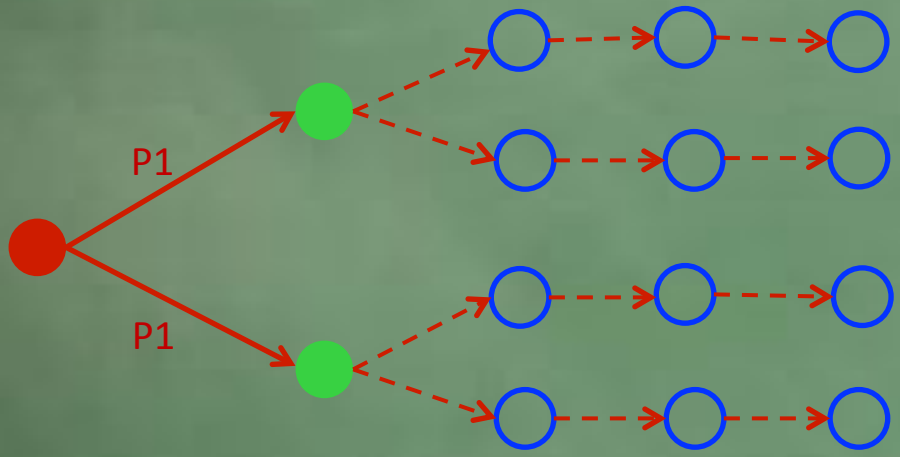
Opportunistic
Overhearing

Tree
Pipelining

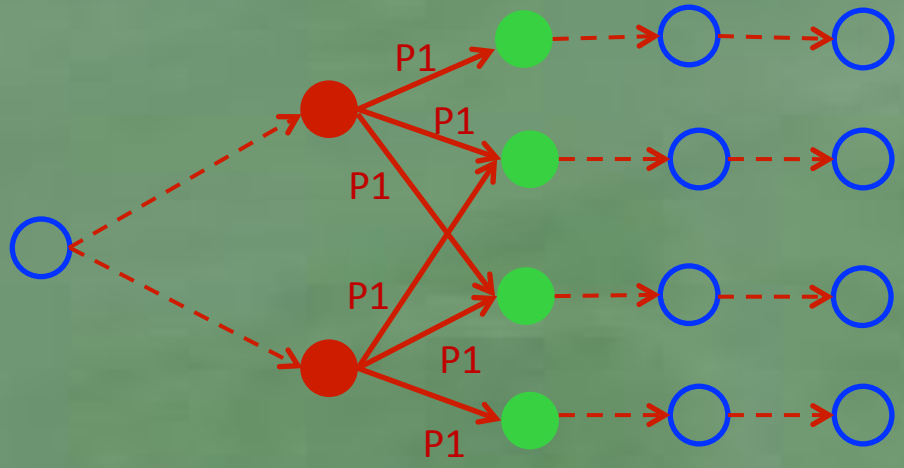
Channel
Cycling

XOR Coding

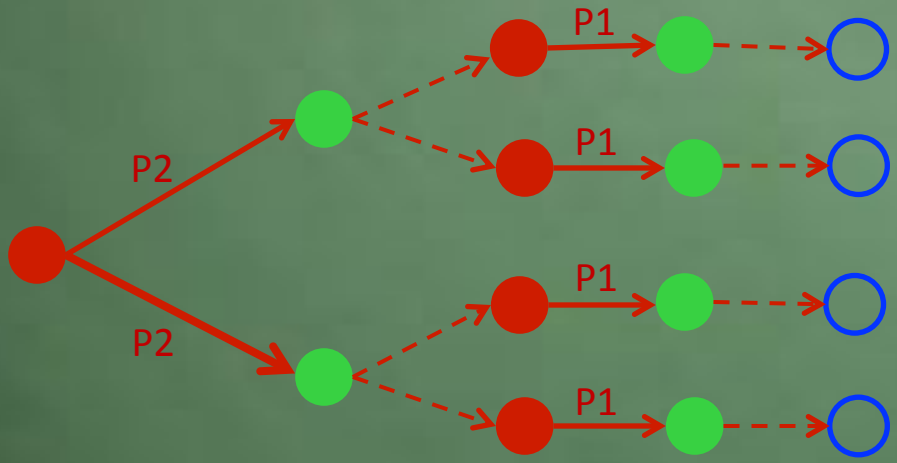




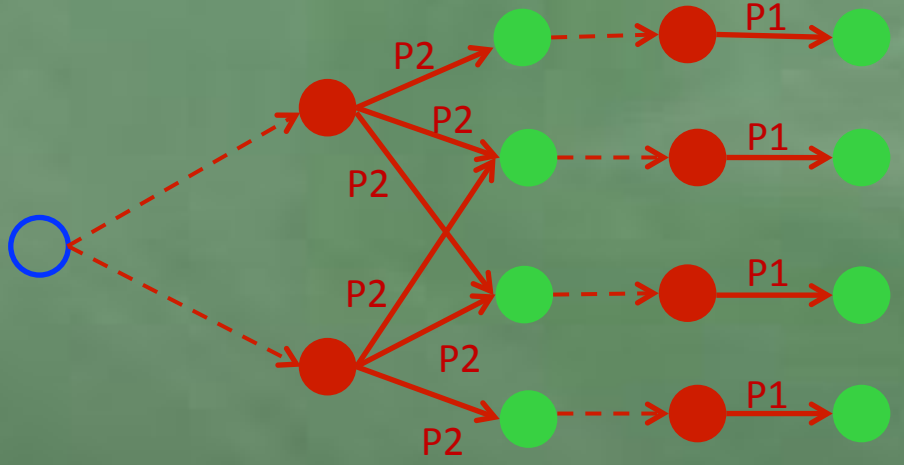
Cycle 1



Cycle 2



Cycle 3



Cycle 4

Transmitting Receiving Idling

SPLASH

Transmission
Density
Diversity

Opportunistic
Overhearing

Tree
Pipelining

Channel
Cycling

XOR Coding

SPLASH

Transmission
Density
Diversity

Opportunistic
Overhearing

Tree
Pipelining

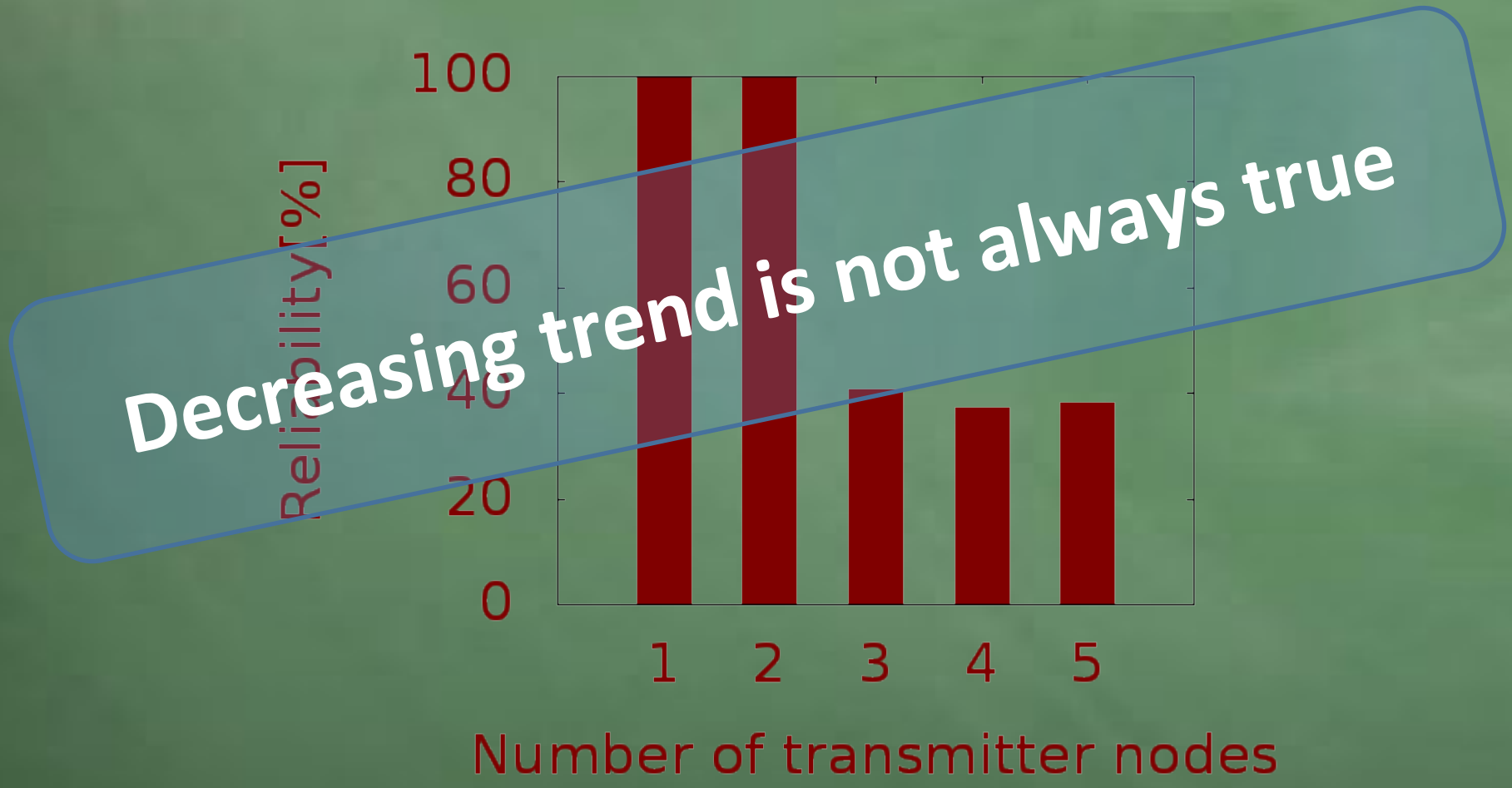
Channel
Cycling

XOR Coding

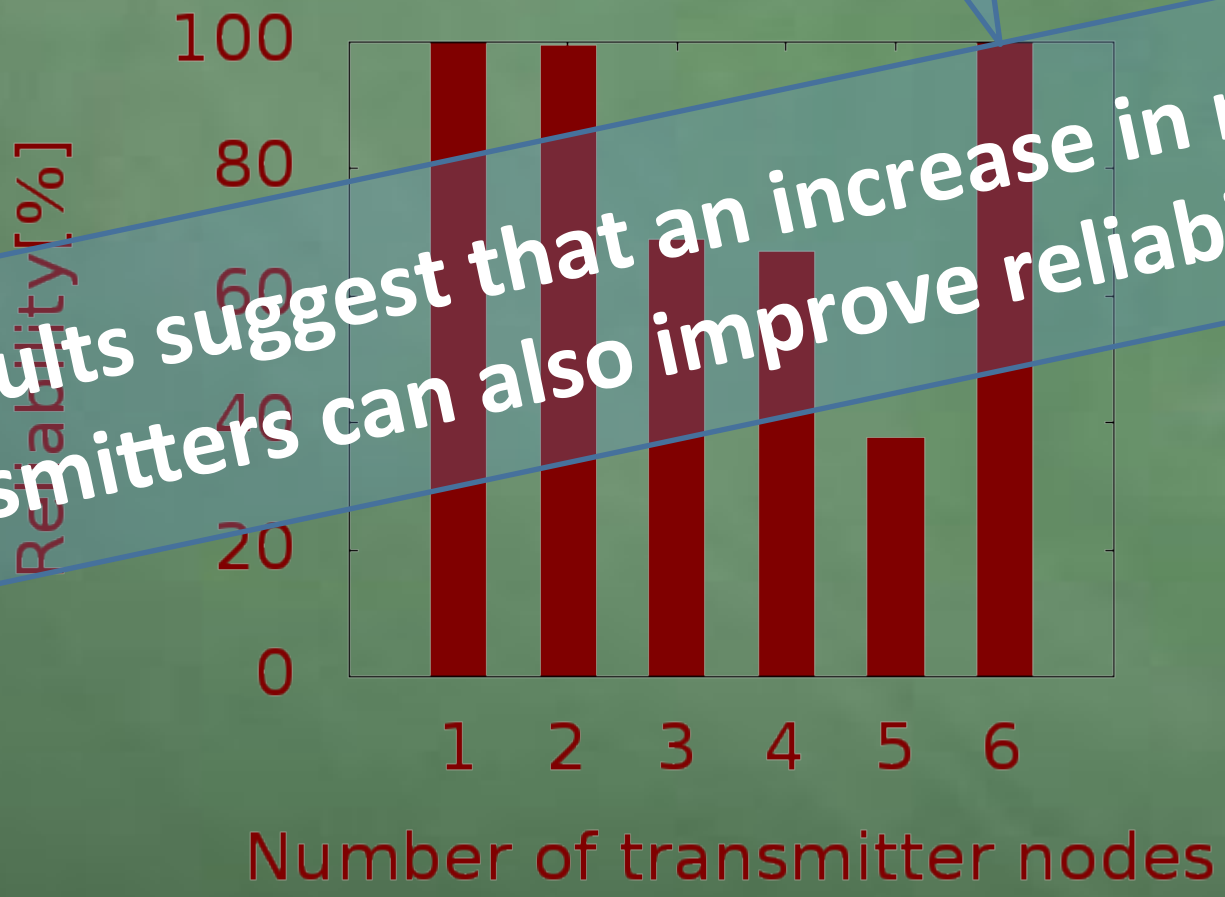
Constructive Interference is not Scalable
[Wang et al. INFOCOM'12]

- The problem is more severe in practice

Constructive Interference is not Scalable



Effect of the *Capture Effect*



Our results suggest that an increase in no. of transmitters can also improve reliability

Splash: Transmission Density Diversity

- First round: only non-leaf nodes forward
  - Typically, more than 50% of the nodes in a tree are leaf nodes [Manjunath et al. RTSS'11]
  - Nodes benefit from low transmission density
- Second round: all nodes transmit
  - Nodes benefit from high transmission density by exploiting capture effect or sender diversity [Rahul et al. SIGCOMM'10]

SPLASH

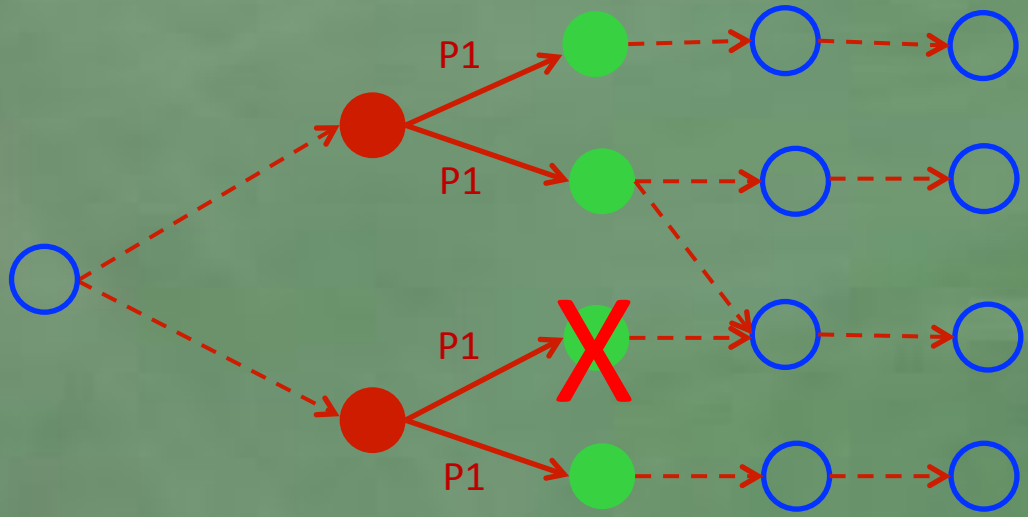
Transmission
Density
Diversity

Opportunistic
Overhearing

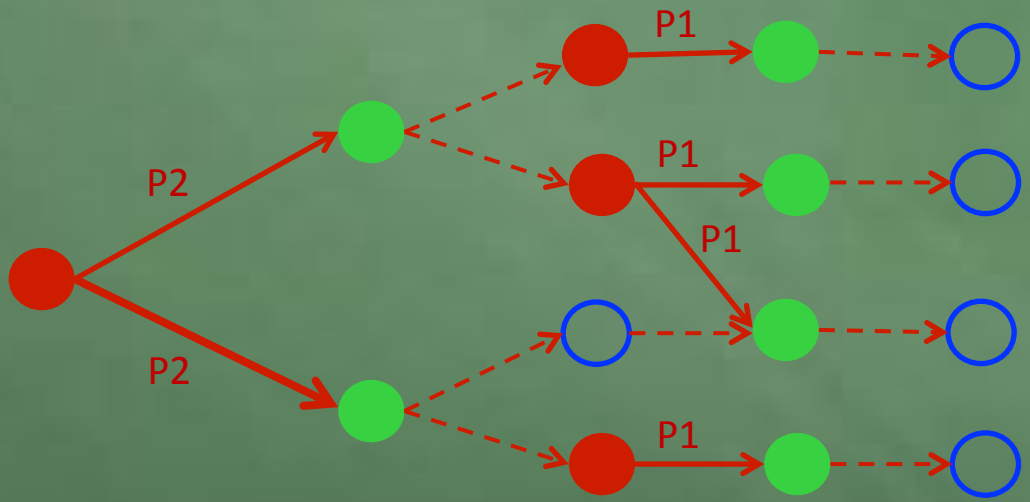
Tree
Pipelining

Channel
Cycling

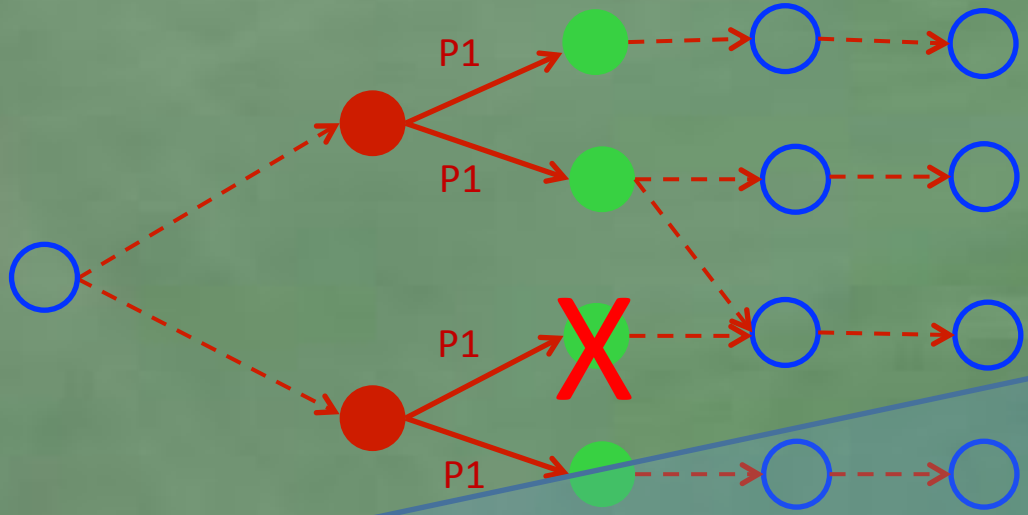
XOR Coding



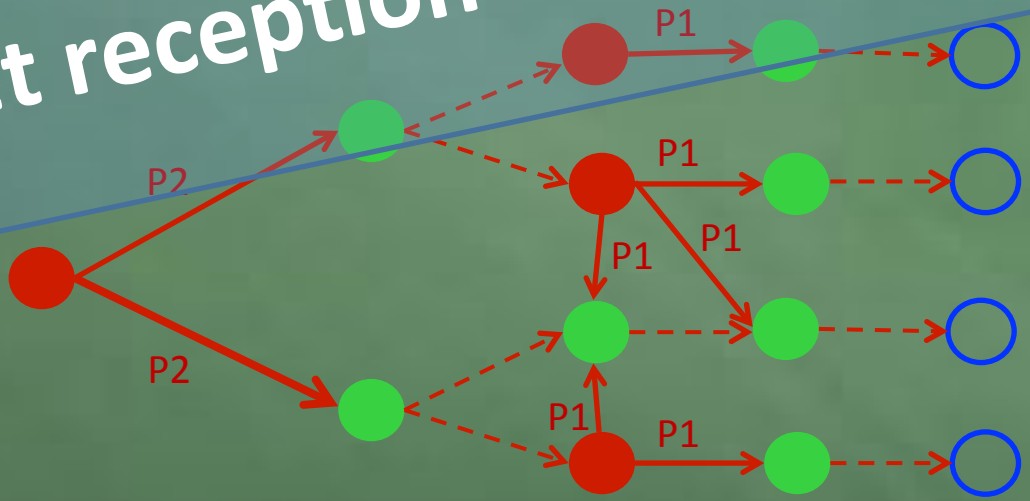
Cycle 2



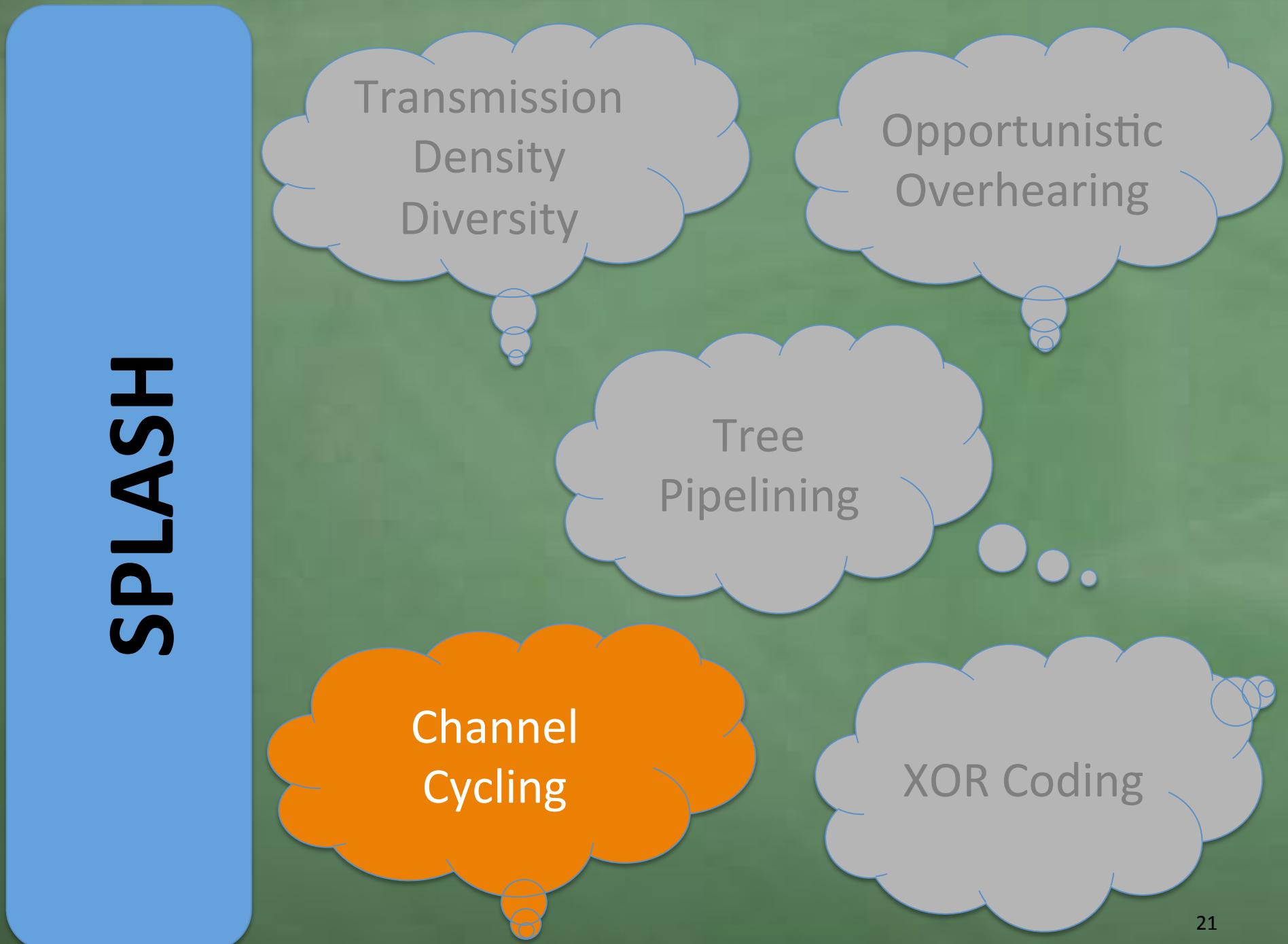
Cycle 3

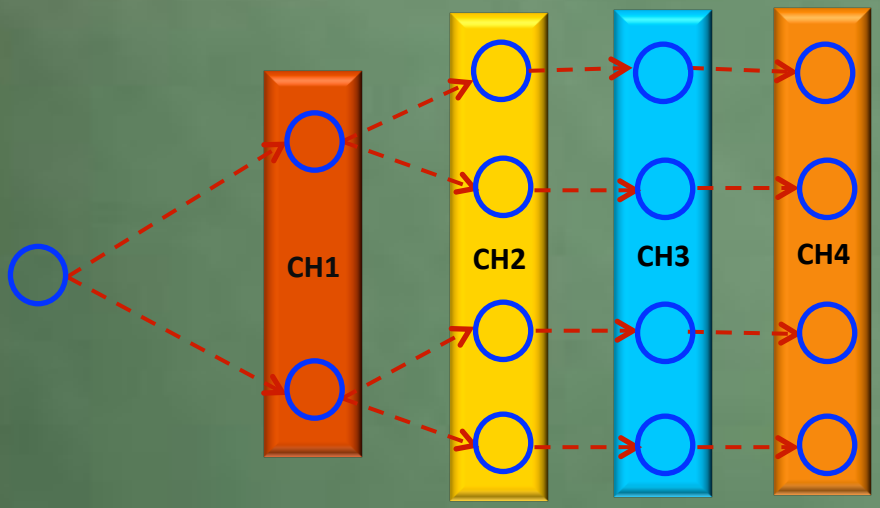


Packet reception chance is doubled

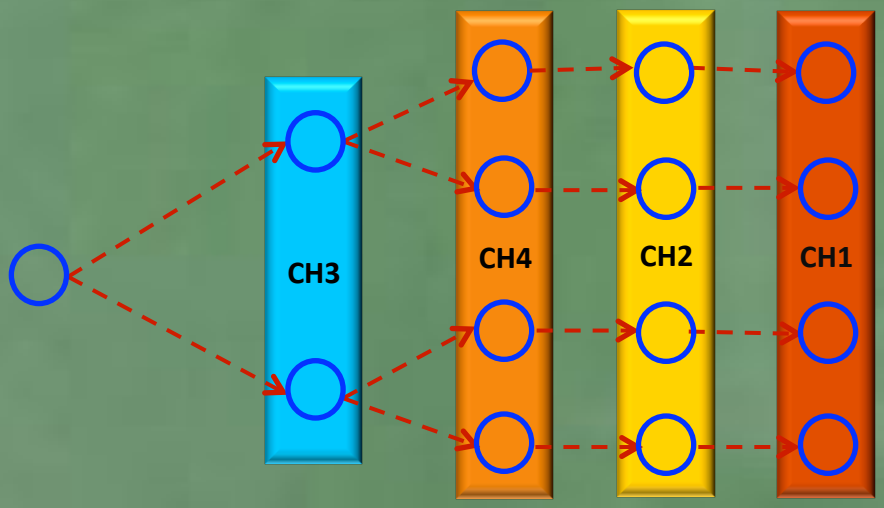


Cycle 3


SPLASH
Transmission
Density
Diversity
Opportunistic
Overhearing
Tree
Pipelining
Channel
Cycling
XOR Coding



Round 1



Round 2

SPLASH

Transmission
Density
Diversity

Opportunistic
Overhearing

Tree
Pipelining

Channel
Cycling

XOR Coding

Splash: XOR Coding

- After two rounds, more than 50% of nodes received most but not full object
- Third round: every transmission is a XOR sum
- Probability that a packet transmission is useful is increased

Splash: Summary of Its Three Dissemination Rounds

Three Rounds of Dissemination

- Transmission Density Diversity
- Opportunistic Overhearing
- Channel Cycling
- XOR Coding

A node in Splash has six chances to receive a packet on up to six different channels

Splash: Local Recovery

- If any missing data is recovered locally
- Neighbor querying and data downloading over CSMA/CA
- Fact that about 90% of nodes have the full object makes local recovery practical


EVALUATION
Outstanding
very Good
Satisfactory
Marginal

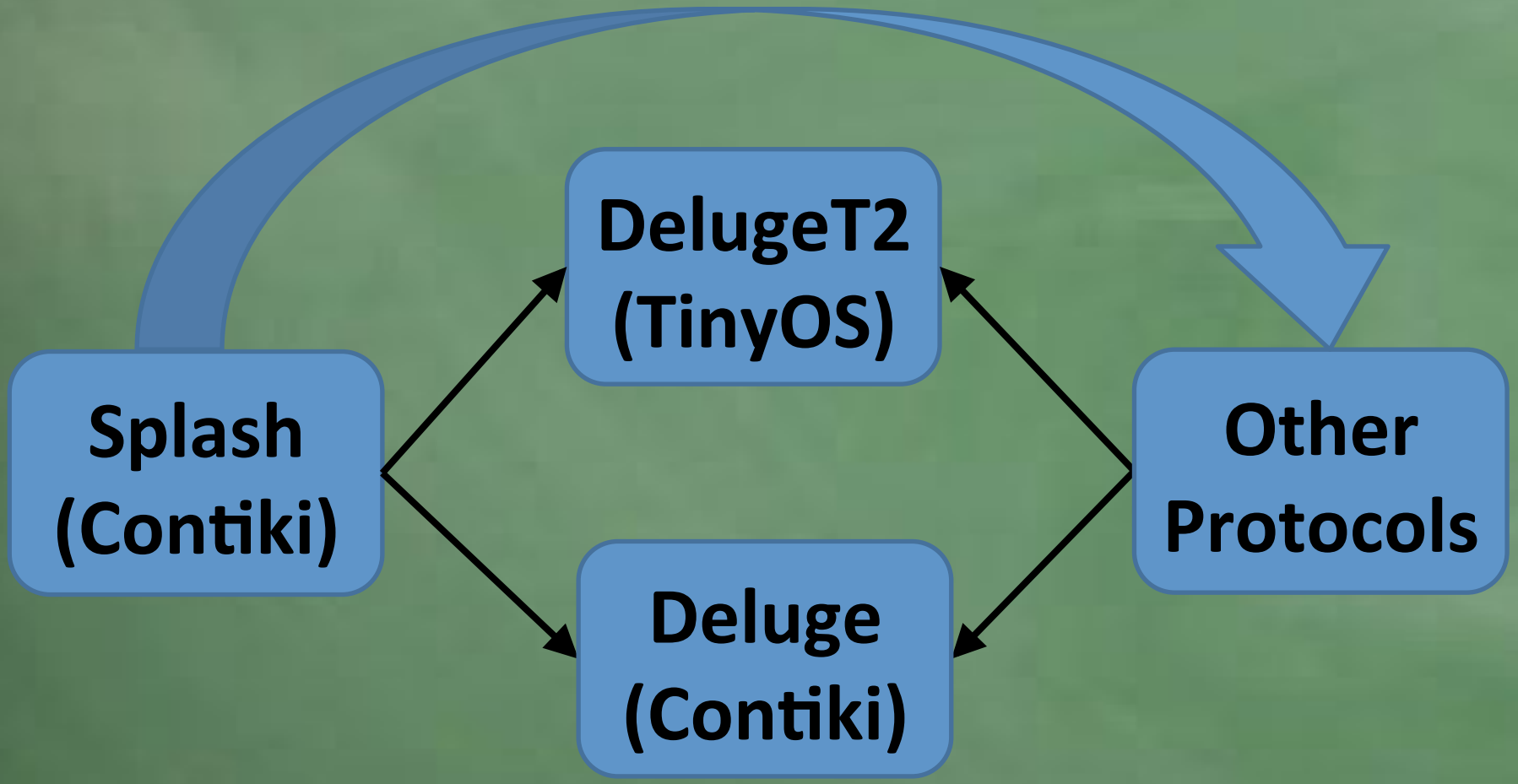
Indriya Testbed

139 TelosB nodes

Twist Testbed

90 Tmotesky nodes

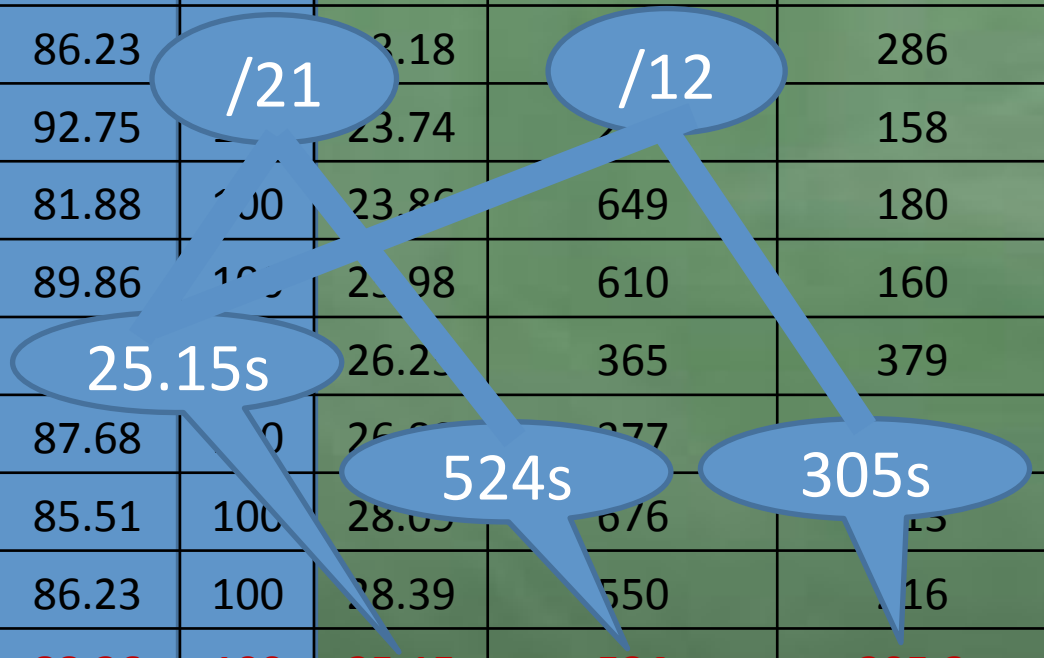
Experimental Setup


DelugeT2
(TinyOS)
Splash
(Contiki)
Other
Protocols
Deluge
(Contiki)

Comparison

Summary of Results on Indriya (32 KB dissemination)

		Splash						DelugeT2	
Tree [no.]	Size [hops]	R1 [%]	R2 [%]	R3 [%]	$N_{R3\text{-}100\%}$ [%]	R_{lr} [%]	T_{Splash} [sec]	$T_{DelugeT2+CTP}$ [sec]	$T_{DelugeT2GI}$ [sec]
1	5	84.54	97.23	98.47	91.30	100	22.49	1300	924
2	6	86.52	96.91	98.58	92.03	100	22.61	286	160
3	7	76.68	94.62	97.80	86.23		.18		286
4	7	88.02	96.12	97.78	92.75		23.74		158
5	9	76.97	93.65	96.69	81.88	00	23.8	649	180
6	7	76.73	95.27	98.16	89.86		2 98	610	160
7	7	80.75	93.51	96.98			26.2	365	379
8	7	83.57	94.43	96.01	87.68	0		377	
9	5	82.46	95.26	97.47	85.51	100	28.0	676	13
10	8	84.28	94.92	96.70	86.23	100	28.39	550	16
Average		**82.05**	**95.19**	**97.46**	**88.26**	**100**	**25.15**	**524**	**305.3**



Summary of Results on Twist (Splash: 32 KB, Deluge: 2KB)

		Splash						Deluge
Tree [no.]	Size [hops]	R1 [%]	R2 [%]	R3 [%]	$N_{R3\text{-}100\%}$ [%]	R_{Ir} [%]	T_{Splash} (32KB) [sec]	T_{Deluge} (2KB) [sec]
1	4	90.58	97.09	99.22	94.38	100	20.07	356.60
2	4	81.08	94.70	99.31	92.13	100	20.19	431.48
3	4	86.53	96.19	98.00	91.01	100	22.79	351.67
4	4	78.64	94.10	98.12	84.09	100	23.37	518.19
5	4	81.42	93.95	97.98	89.89	100	23.41	467.00
6	4	78.04	93.55	96.82	85.39	100	26.66	439.81
7	4	83.90	95.18	97.54	89.8		26.79	345.28
8	4	83.70	93.64	96.45	84.27	100	27.32	388.68
9	6	81.58	93.35	97.02	85.39	100	27.45	484.10
10	5	80.78	93.09	97.11	85.39	100	29.25	497.59
Average		**82.62**	**94.48**	**97.76**	**88.18**	**100**	**24.73**	**418.04**

24.73s

418s

Comparison to Other Approaches (Baseline: DelugeT2)

Protocol	No. of nodes	File size [KB]	Reduction factor
MNP (2005)	100	5	1.21
MC-Deluge (2005)	25	24.3	1.6
Rateless Deluge (2008)	20	0.7	1.47
ReXOR (2011)	16	4	1.53
ECD (2011)	25	10	1.44
MT-Deluge (2011)	20	0.7	2.42
Splash	139	32	21

Evaluation of Individual Techniques

XOR coding

Opportunistic Overhearing

Channel Cycling

Transmission Density Diversity

Local Recovery

Evaluation of Individual Techniques

XOR Coding: increases percentage of nodes having the full object from 37% to 88%

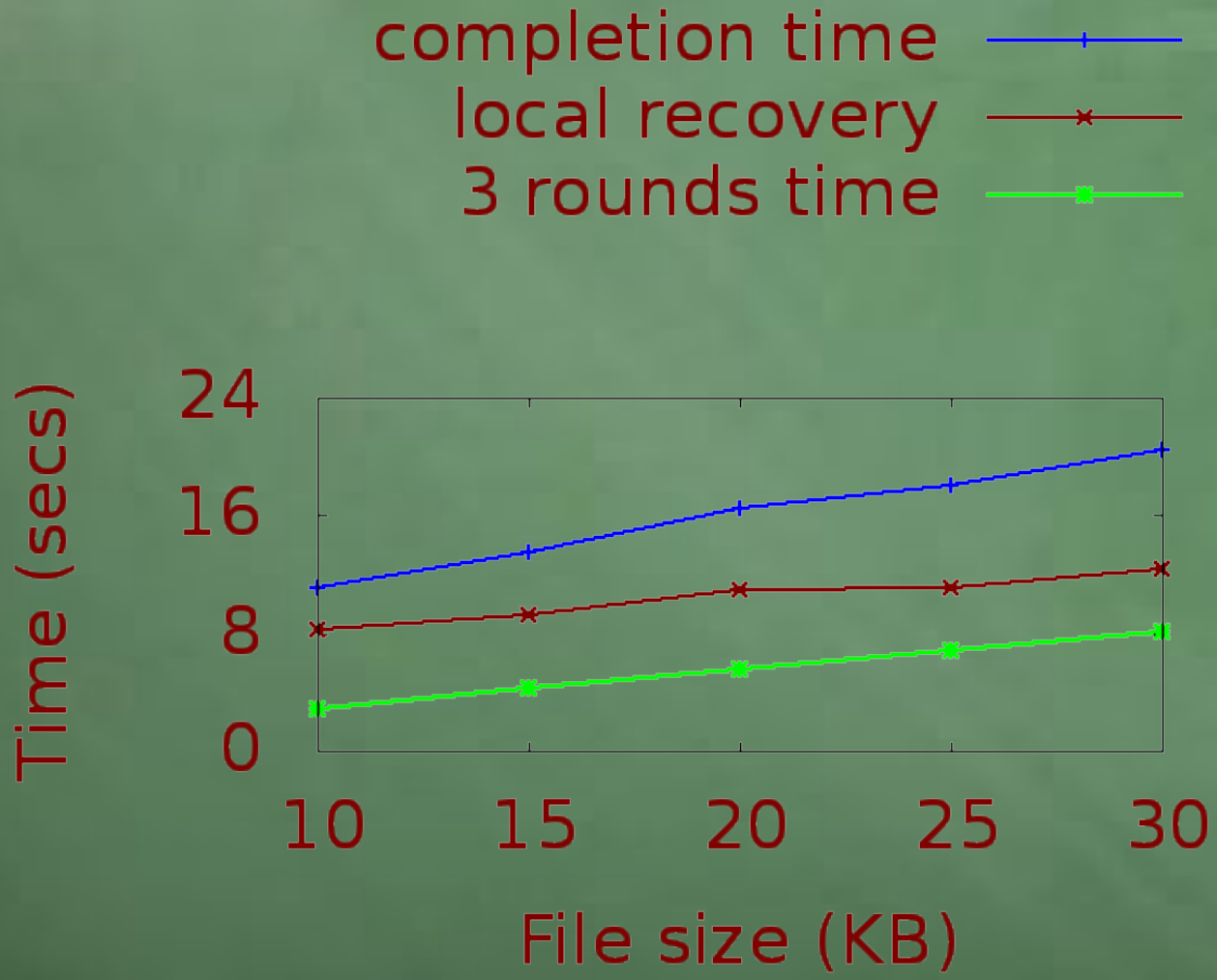
Opportunistic overhearing: decreases dissemination time by 26%

Evaluation of Individual Techniques

Channel Cycling: decreases dissemination time by 25%

Transmission Density Diversity: 39% and 18% of nodes benefit from low and high transmission densities respectively

Local Recovery



Local Recovery

Conclusion

- We designed and implemented Splash, a fast data dissemination protocol
- Key factors are constructive interference, channel diversity and techniques for reliability
- Splash reduces completion time by an order of magnitude

Thank you

References

Some of the images in these slides are downloaded from Google Images and Kalyan Varma's websitehttp://kalyanvarma.net/