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Overlapped NACKs: Improving Multicast Performance in Multi-access Wireless Networks

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Outline

- Basic problem
- Our approach
- Case study: Bluetooth
- Performance comparison
- Conclusion

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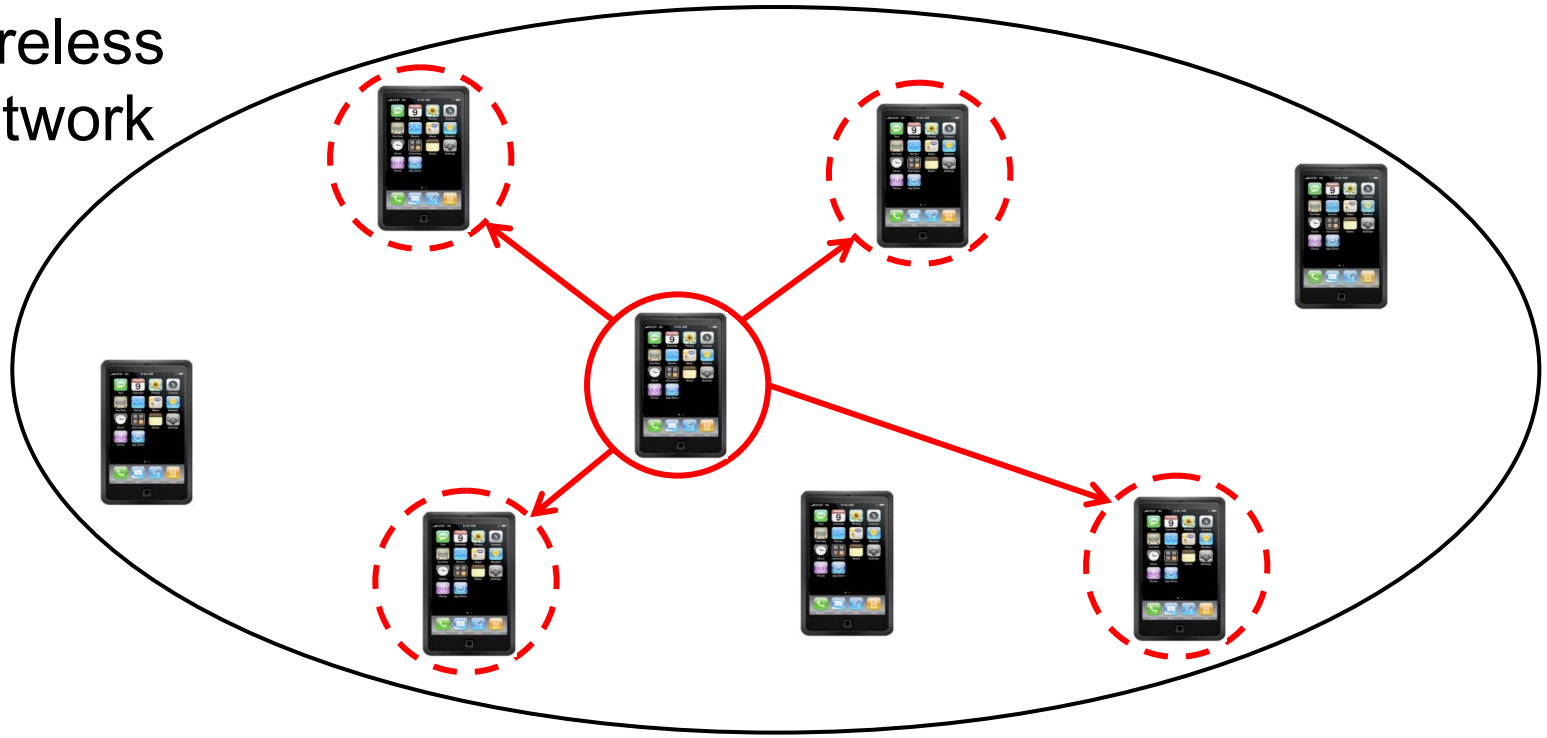
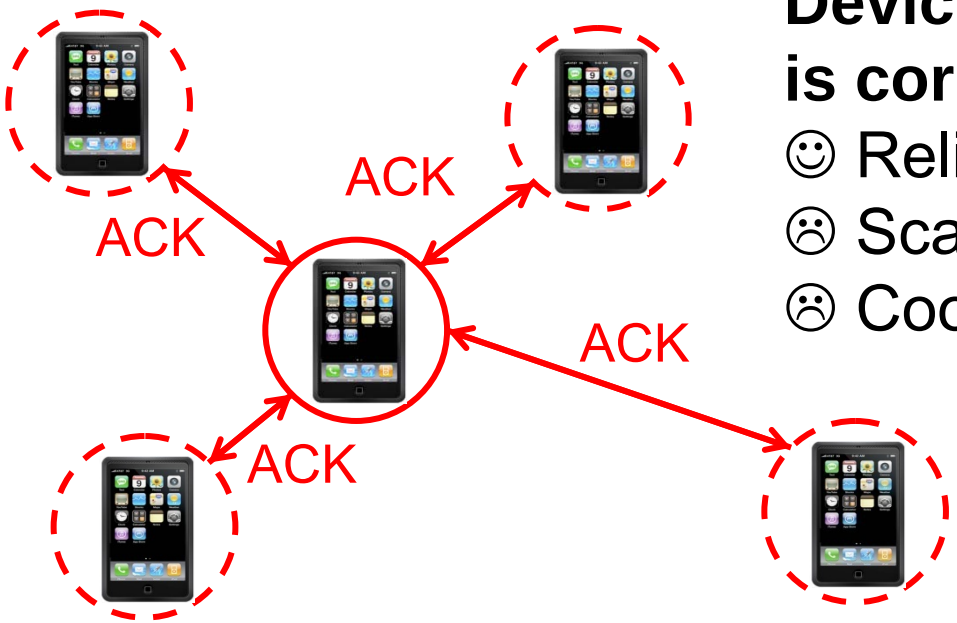
Multicast communication



Multicast: only 1 transmission!!!
-> resource saving (time/frequency, power)
☺ Increasing rate
☺ More bandwidth for other devices/applications

ACK based reliability



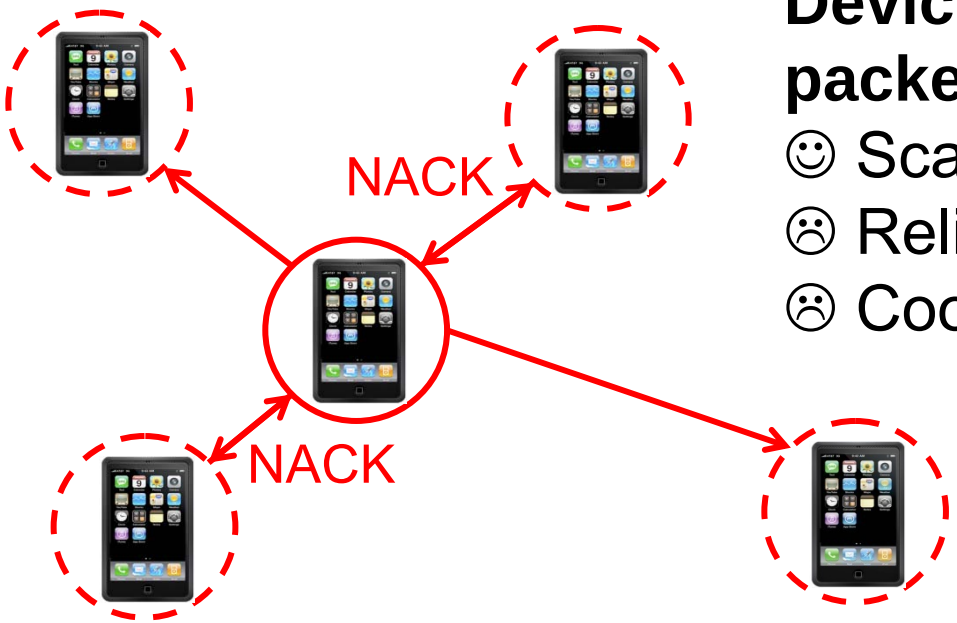
Devices send ACKs if the packet is correctly received

☺ Reliability

☹ Scalability

☹ Coordination mechanism

NACK based reliability



Devices send NACKs if the packet is NOT correctly received

☺ Scalability

☹ Reliability

☹ Coordination mechanism

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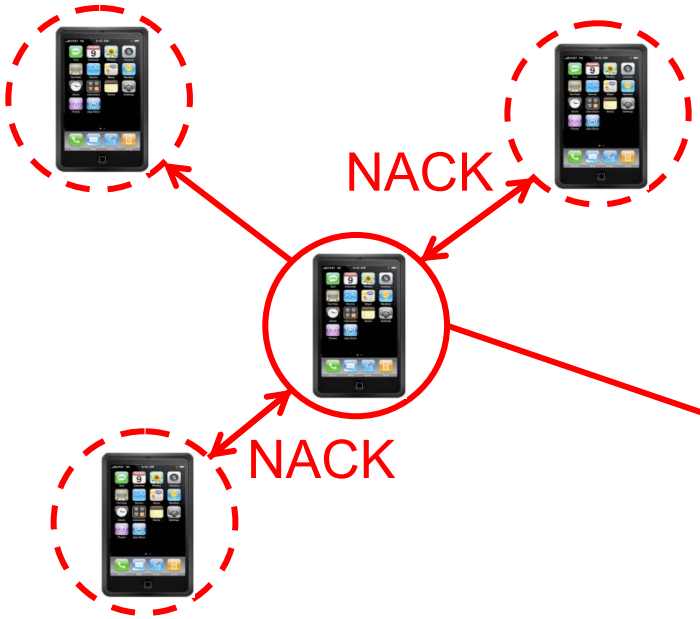
Overlapping NACKs

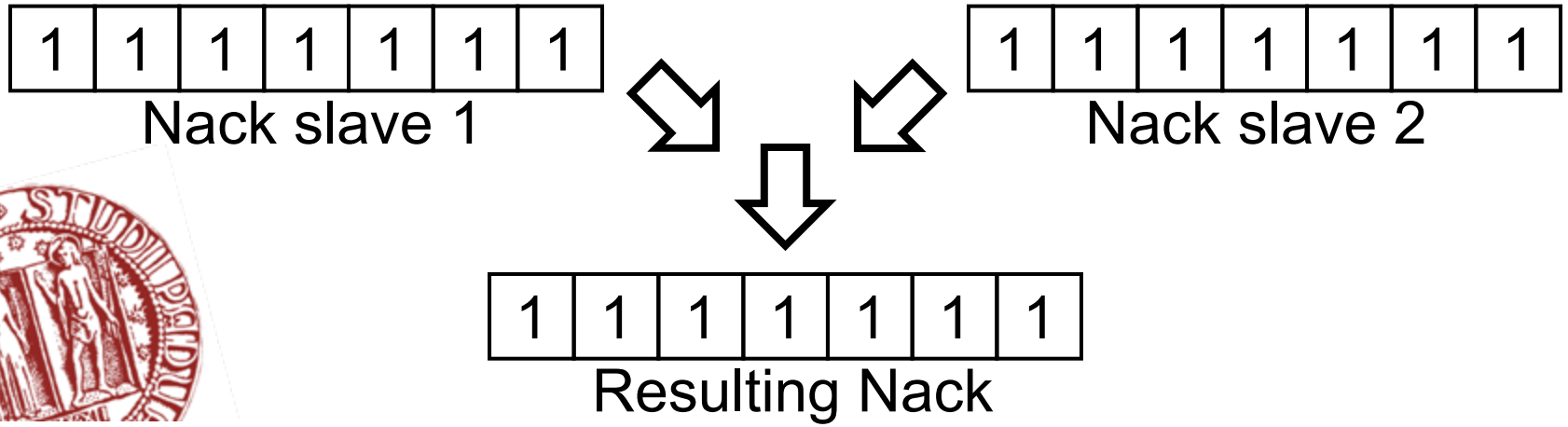


NACKs sent in the same resource!! (-> collisions)

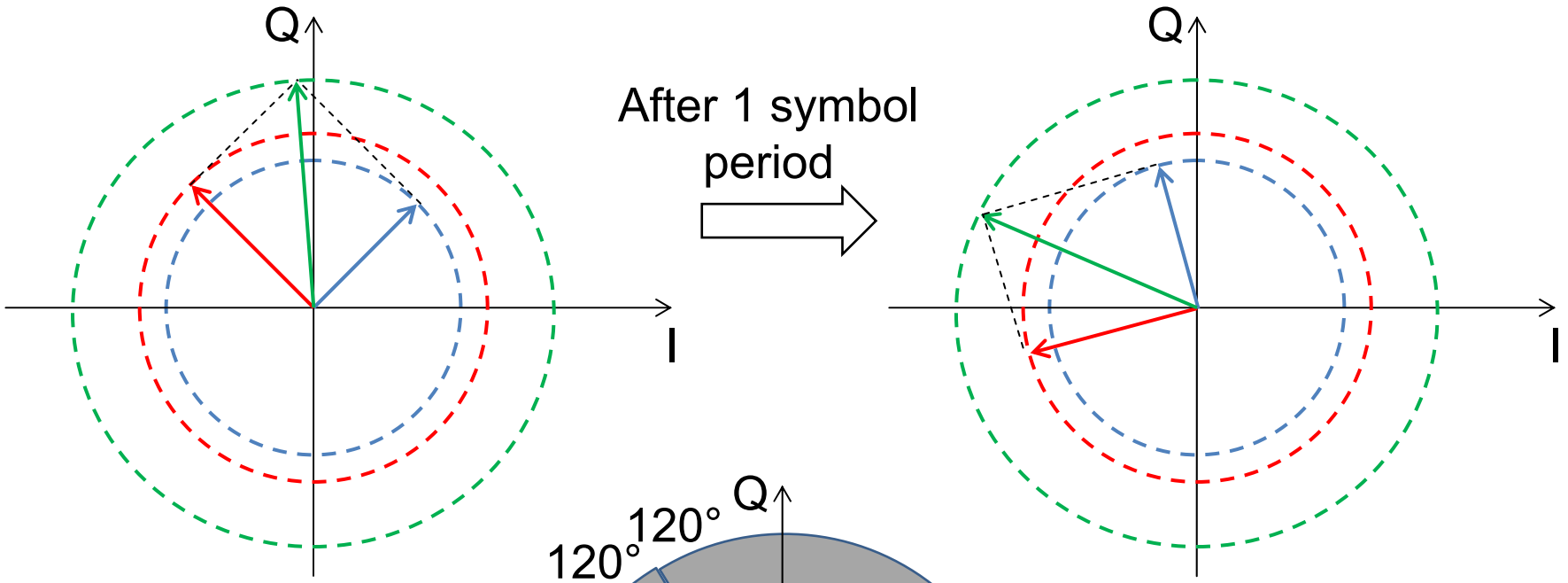
☺ Scalability

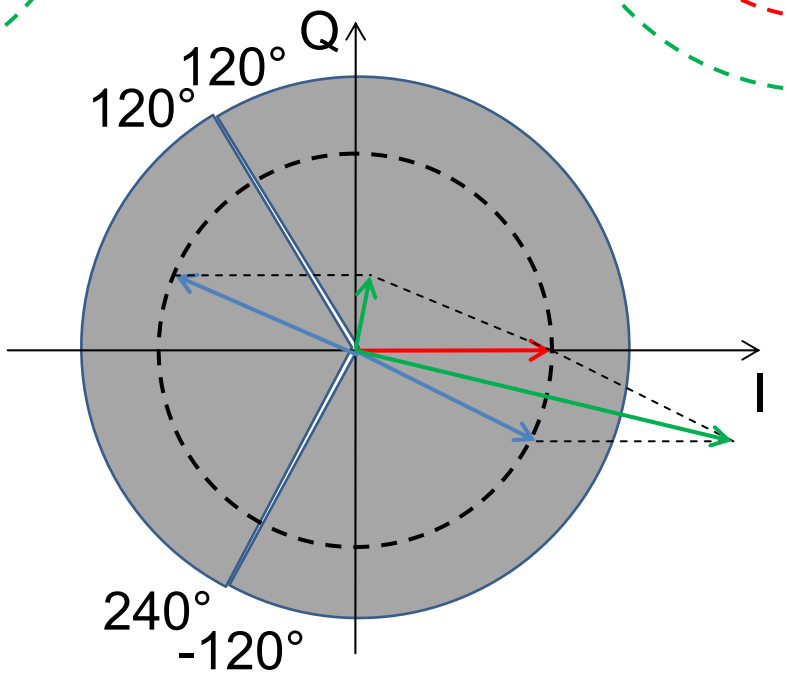
☺ No coordination mechanism

? Reliability



DPSK example





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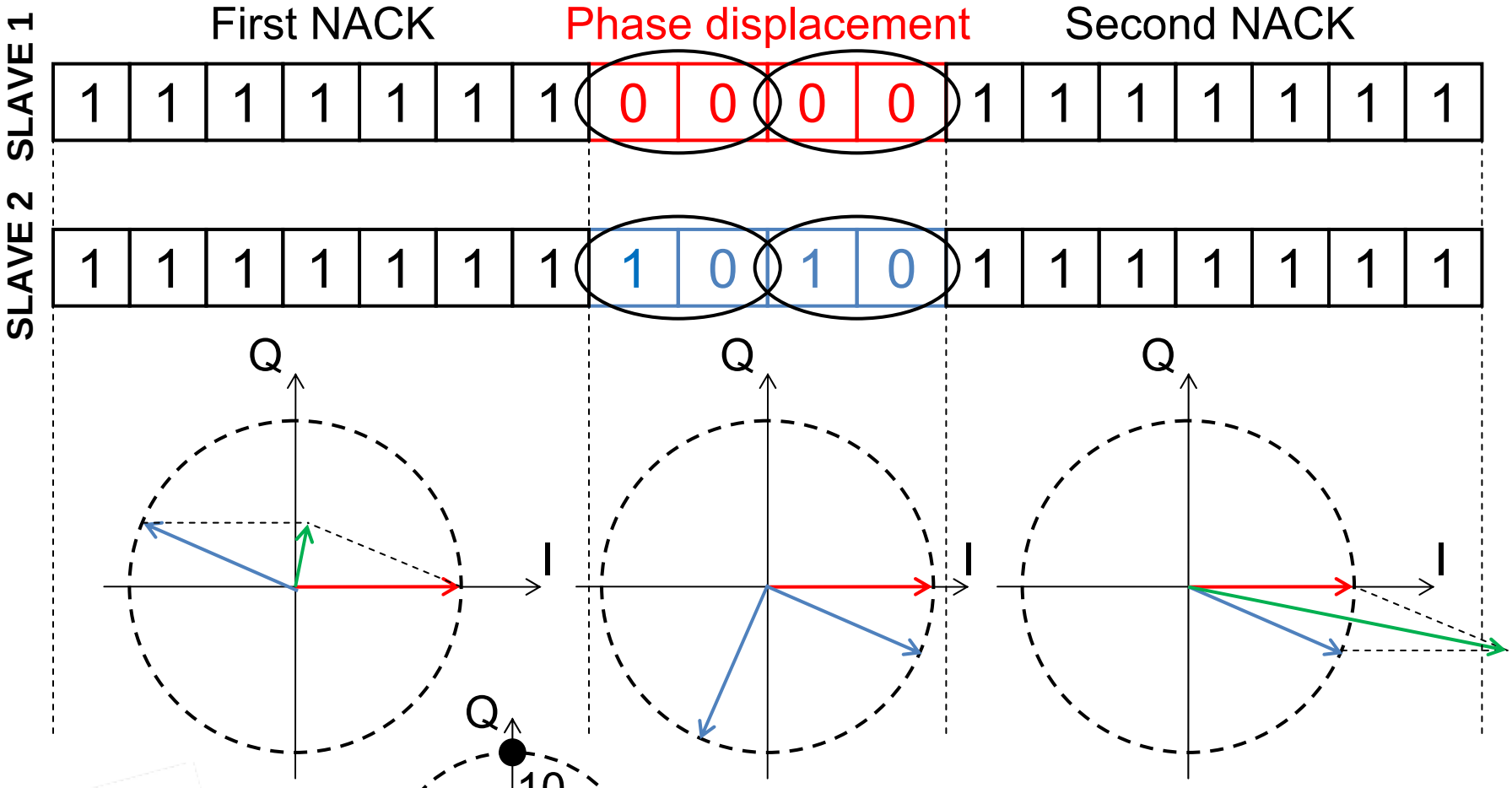
Double-NACK structure



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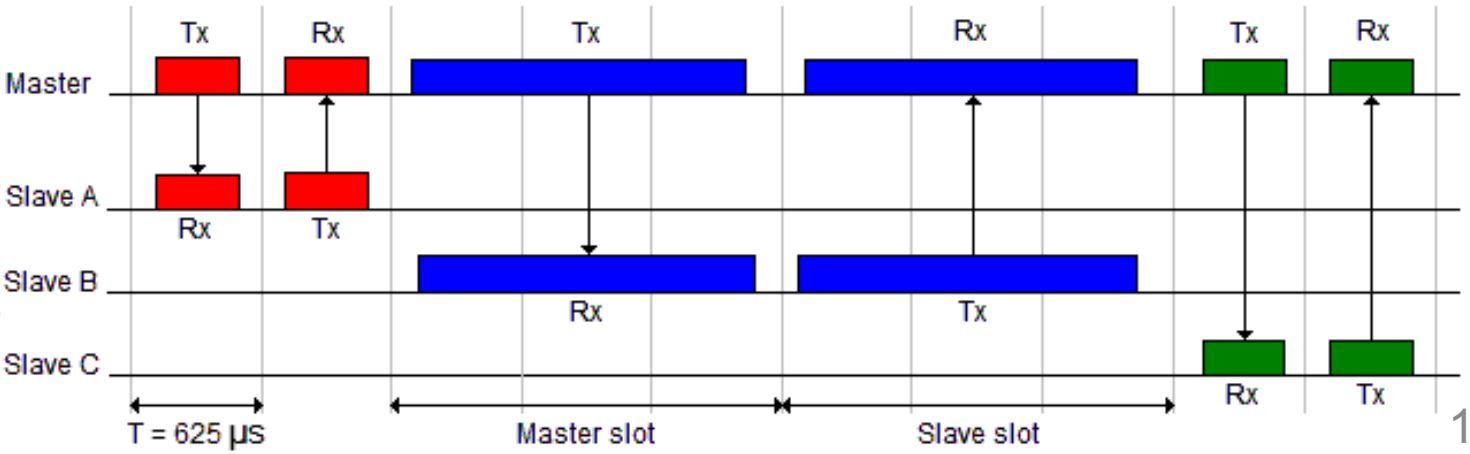
Bluetooth technology

- Ad-hoc Personal Area Network (PAN)
- Direct communication only between master and slaves
- Time-Division Duplexing (TDD) communication
- Packets last 1, 3 or 5 slots
- GFSK (1 Mbps), π/4-DPSK (2 Mbps), 8DPSK (3 Mbps)
- **No multicast (multi-unicast) !!!**

  -> SIG proposal



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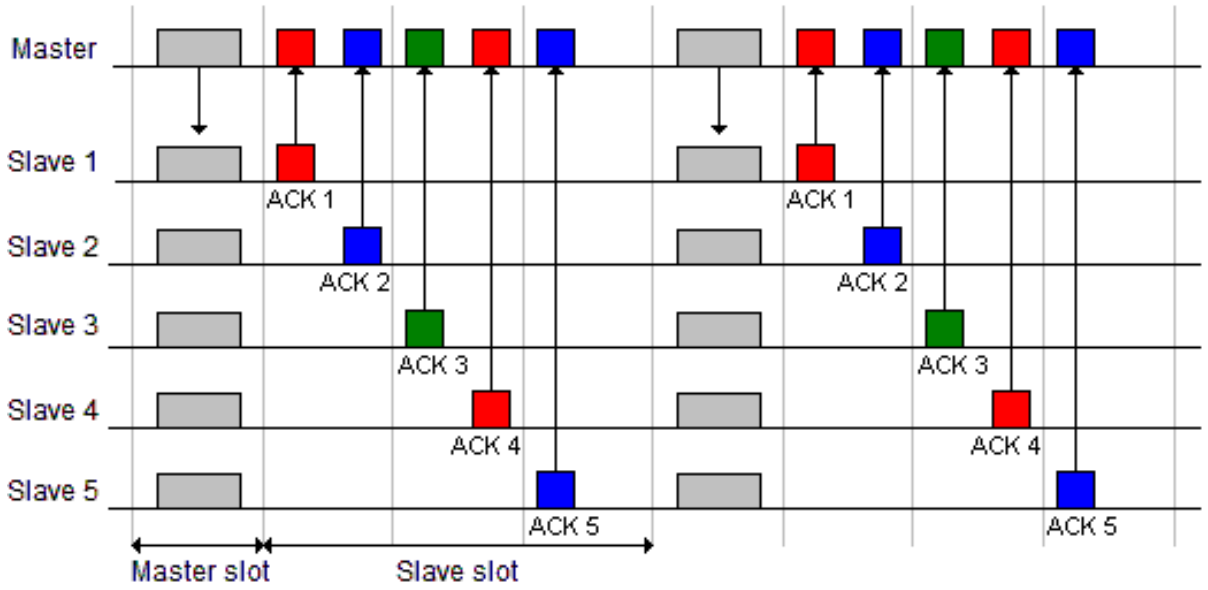
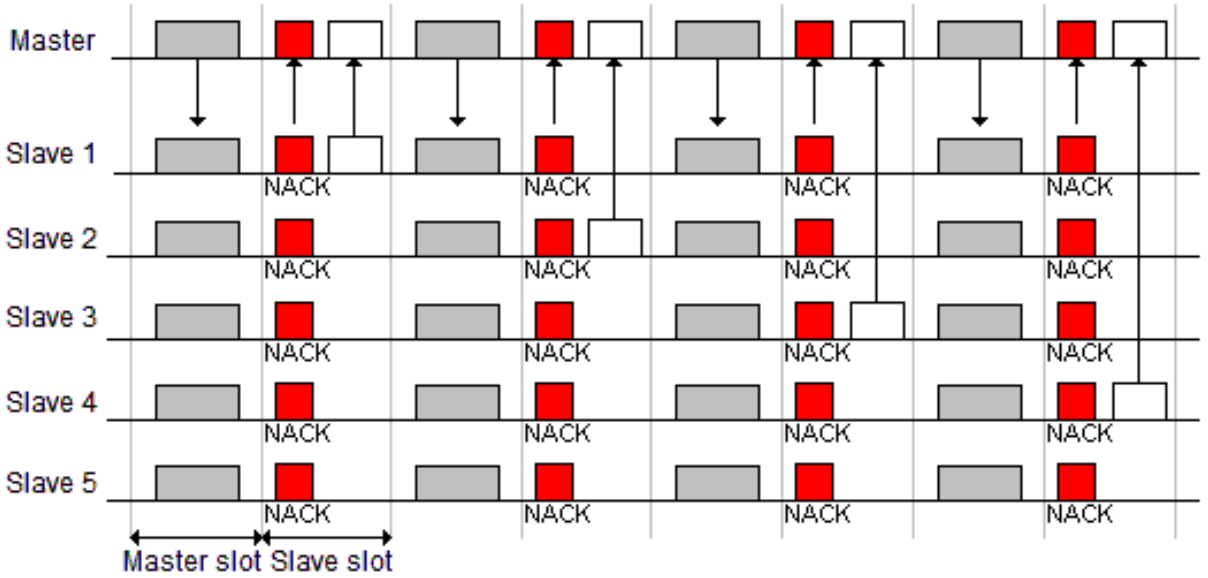
ACK and NACK based protocols

SIG (Special Interest Group) proposal



Our proposal Overlapped NACKs



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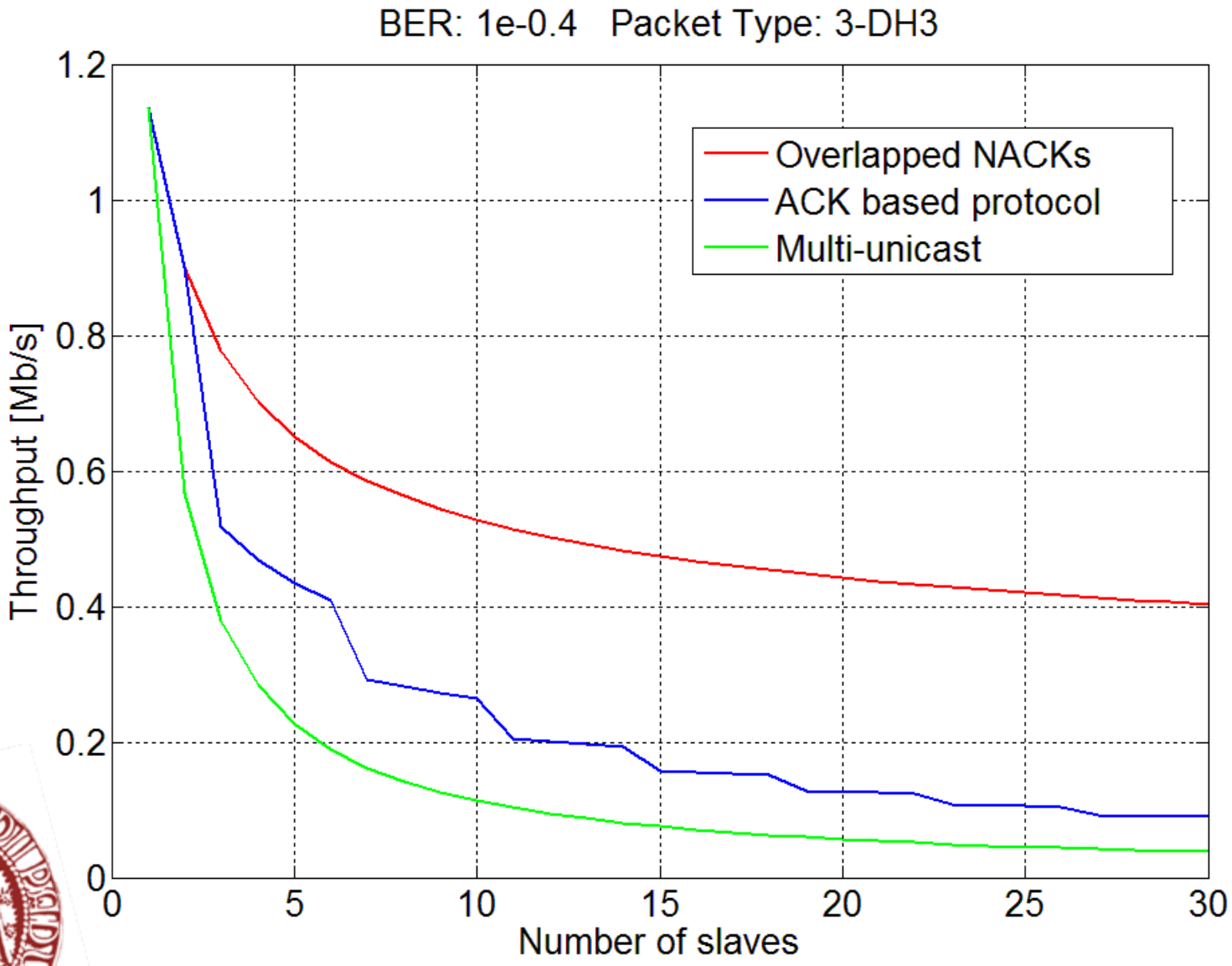
Throughput vs slaves



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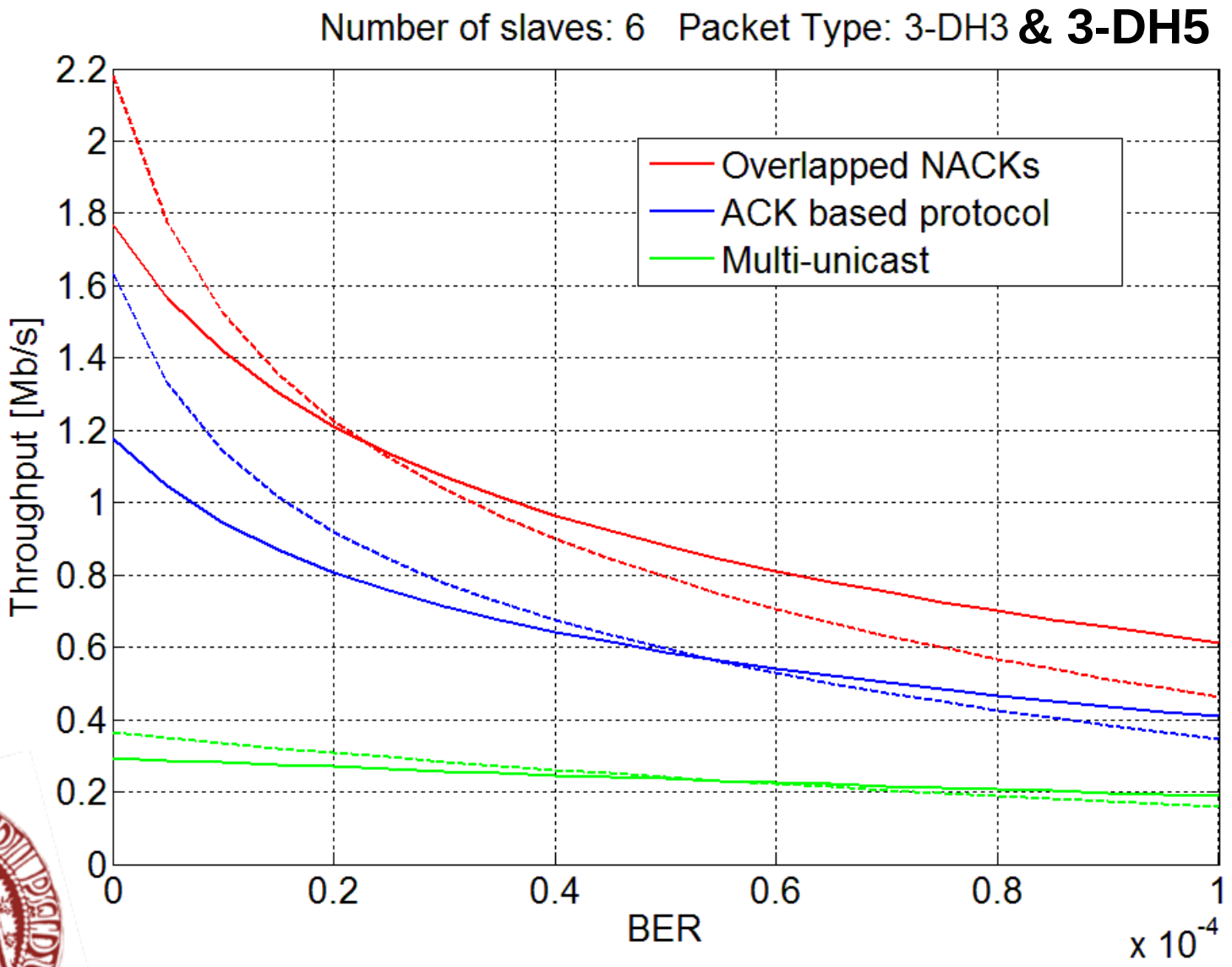
Throughput vs BER



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Reliability

Average PER / Worst case PER

	BER=1E-5	*BER=1E-4*
DH1	6.9E-11 / 2.1E-10	6.3E-09 / 1.9E-08
DH3	3.0E-09 / 9.0E-09	1.7E-07 / 4.9E-07
DH5	9.7E-09 / 2.9E-08	3.5E-07 / 1.0E-06
2-DH1	2.7E-10 / 8.2E-10	2.3E-08 / 6.8E-08
2-DH3	1.1E-08 / 3.4E-08	3.8E-07 / 1.1E-06
2-DH5	3.4E-08 / 1.0E-07	6.6E-07 / 1.9E-06
3-DH1	6.4E-10 / 1.9E-09	4.9E-08 / 1.4E-07
3-DH3	2.4E-08 / 7.1E-08	5.5E-07 / 1.6E-06
3-DH5	6.9E-08 / 2.0E-07	9.9E-07 / 2.8E-06

On average 1 packet every 625000 is lost !!!

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Conclusion

1. New simple NACK based protocol for reliable multicast communications
2. NACK structure to be robust to collisions
3. Comparison with an ACK based protocol for Bluetooth
4. Results show:
    - Little reliability loss
    - High throughput gain

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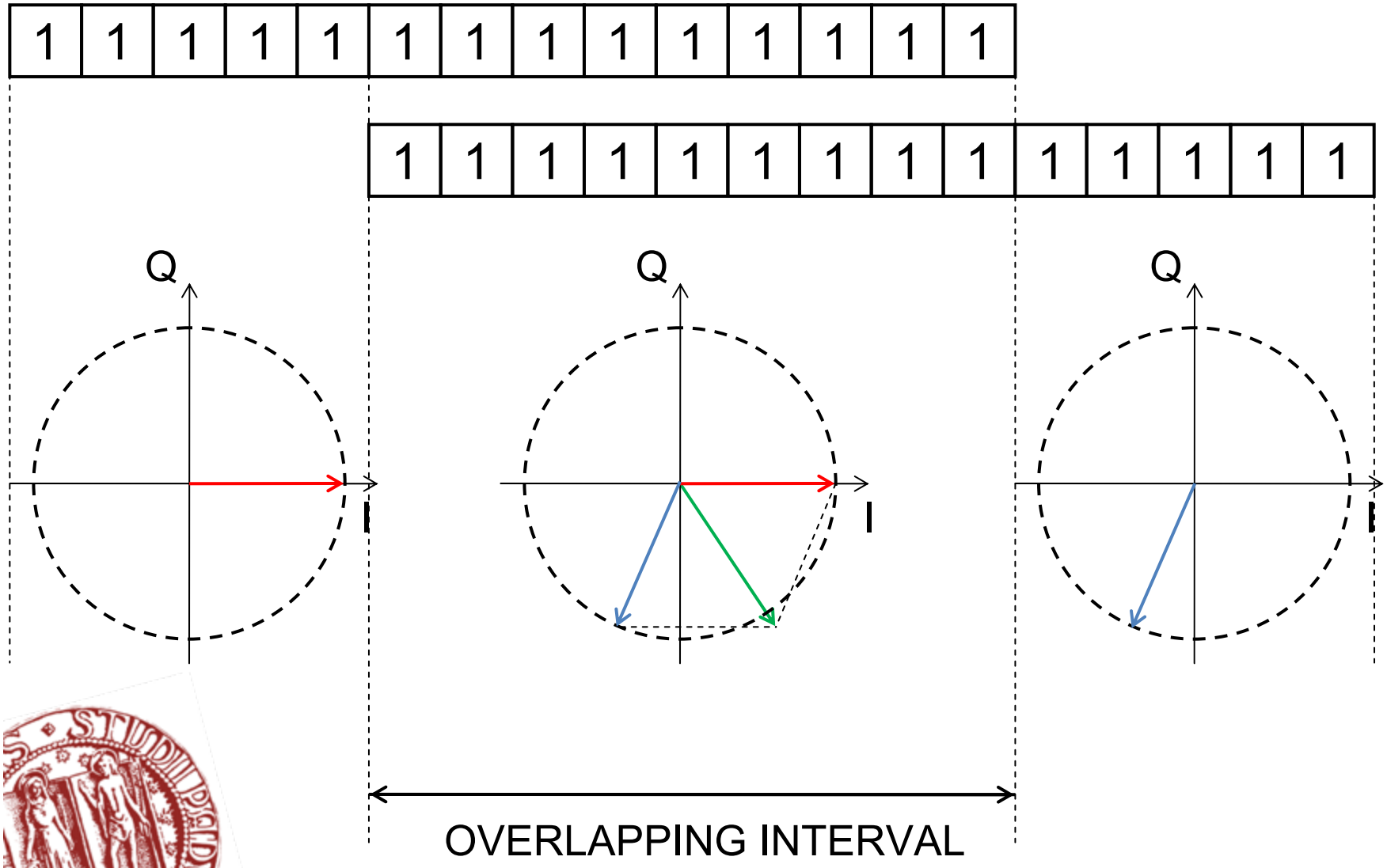
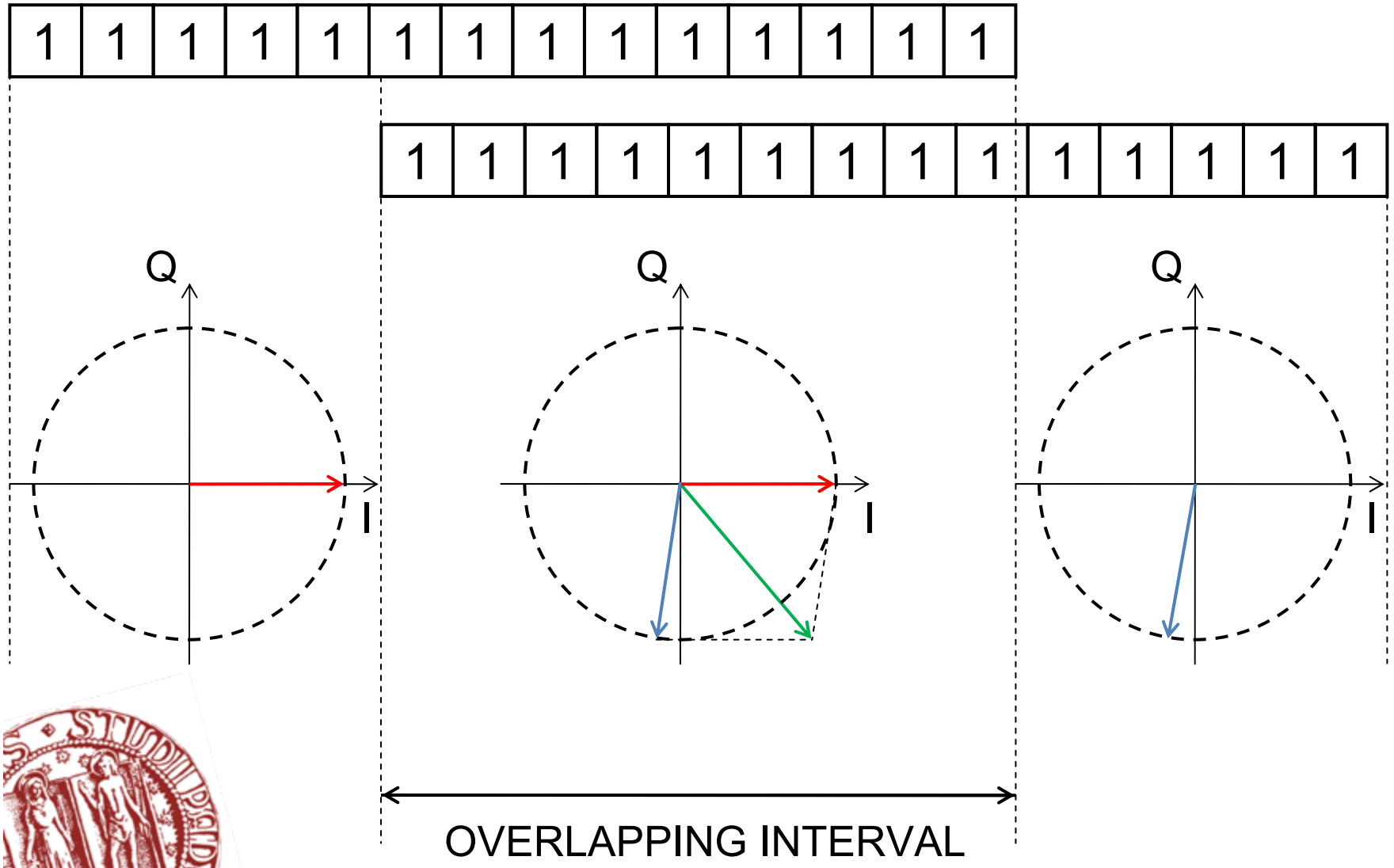
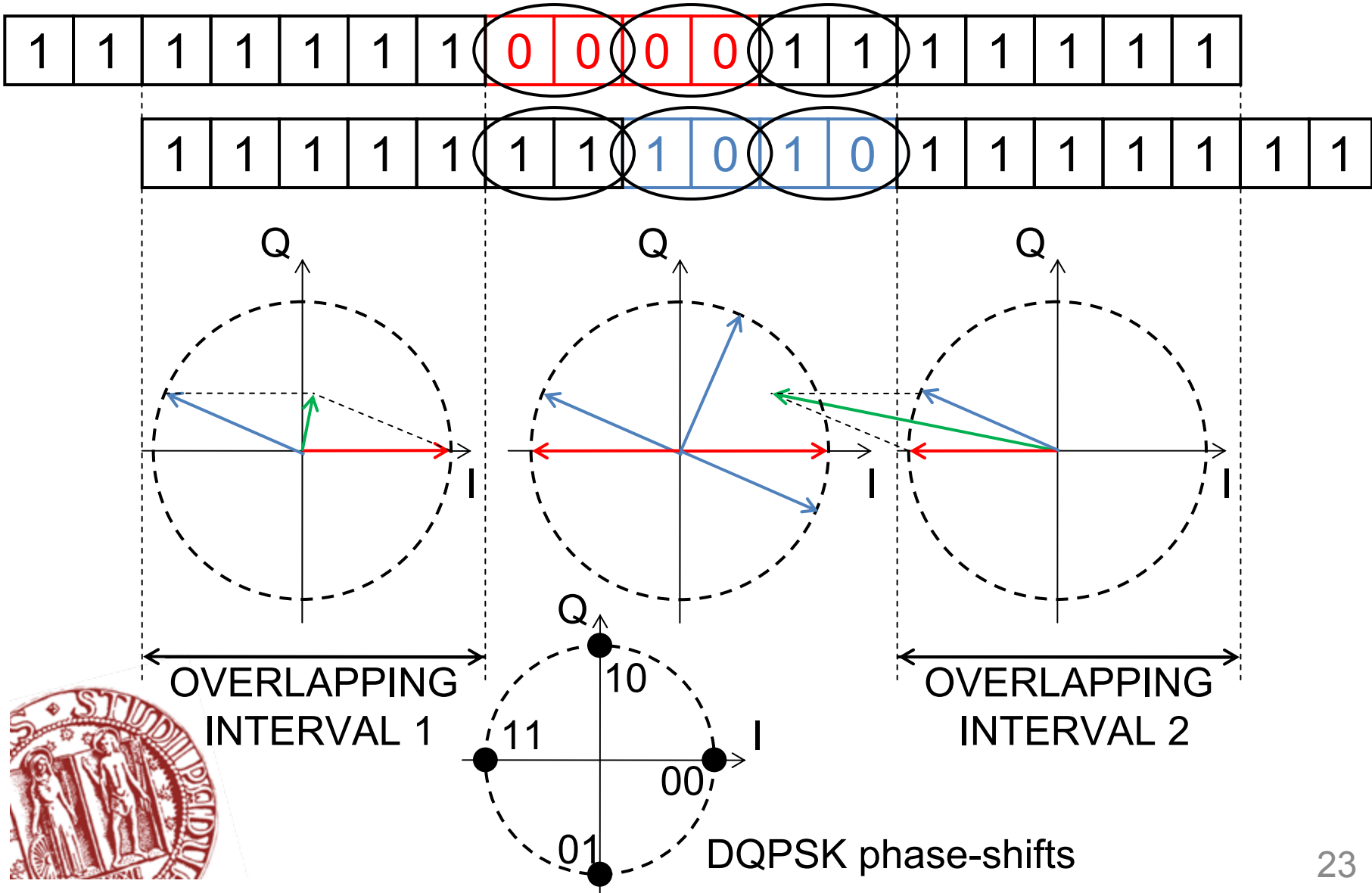
Time synchronization



Time synchronization

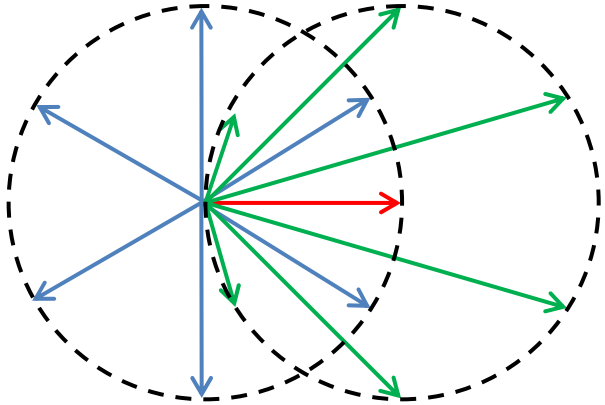


Time synchronization



Frequency offset

Equal amplitude case



Red turns of 0°
Blue turns of 60°

Green turns of 30°

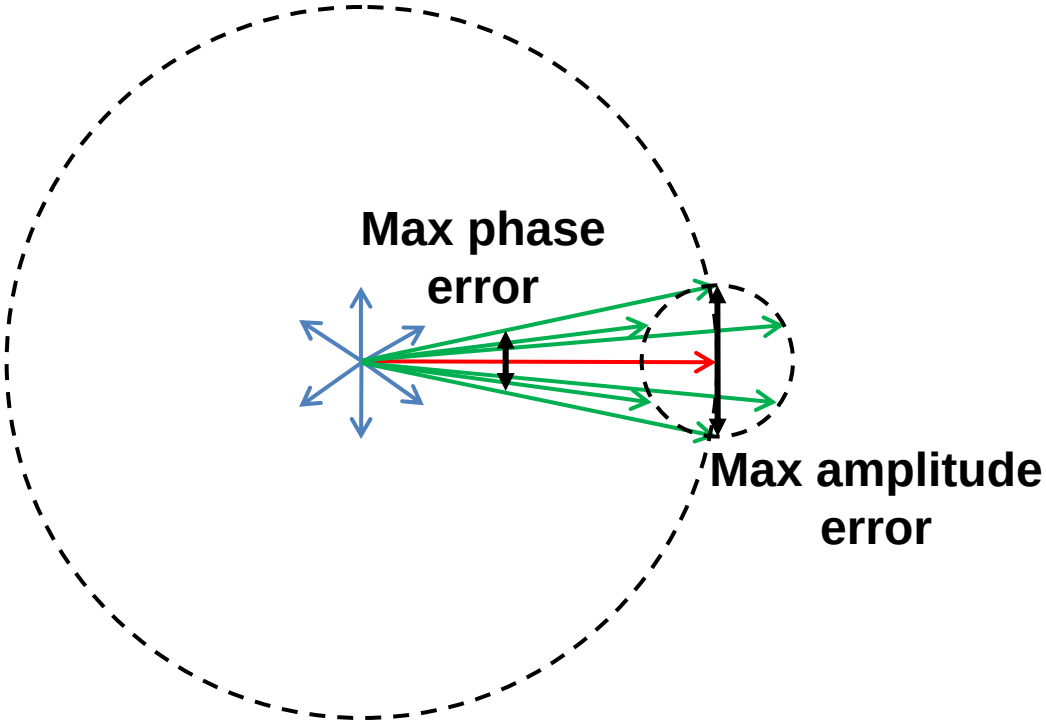
Green turns of 210°!!!
-> discontinuity of 180°

Conclusion:

- Most time high SNR and constant phase drift
  -> it can be compensated
- Some time SNR drastically decreases and phase discontinuity
  -> this must be taken into account to set correlator threshold

Frequency offset

1 signal much stronger than the other

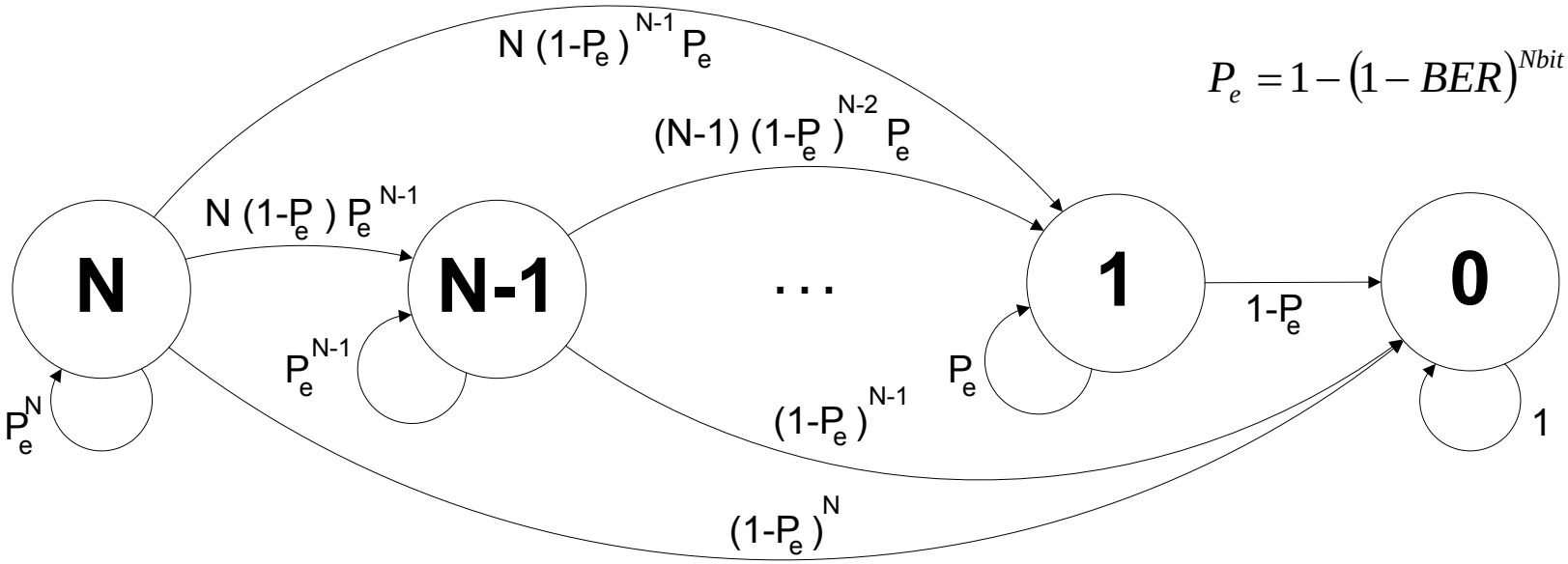


Red turns of 0°
Blue turns of 60°

Green ~ Red + noise

Conclusion:
SNR of the received signal decreases a little

Markov model



$$P_e = 1 - (1 - BER)^{Nbit}$$

$$P_{i,j} = \begin{cases} \binom{i}{j} \cdot P_e^{\,j} \cdot (1 - P_e)^{i-j} & j \le i \\ 0 & otherwise \end{cases} \qquad i, j = 0,1,\ldots, N$$

Renewal Process: $Th = \lim_{t \to \infty} \frac{bits\ transmitted\ until\ t}{t} = \frac{b}{d}$

b: average number of bits transmitted in a cycle

d: average duration of a cycle

Markov model

$P_{nr}(i)$ Probability that the master does not recognize the overlapping of i double NACKs (missed detection probabilities)

P_{L_i} Probability to be absorbed in L_i

$$\underline{PER} = \sum_{i=1}^{N} \frac{i}{N} \cdot P_{L_i}$$

$$B = \sum_{i=1}^{N} P_{L_i}$$