XOR Rescue: Exploiting Network Coding in Lossy Wireless Networks

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26 June 2009 @ SECON, ROME, Italy

Outline

- Introduction
- “XOR Rescue” (XORR) Design
- Performance Evaluation
- Conclusion

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Problem

- New wireless applications demand high performance
- But: wireless channels are loss-prone
  - Average loss rate is 20-40 %, due to
    - Interference
    - Noise
    - Attenuation
    - Mobility, etc…

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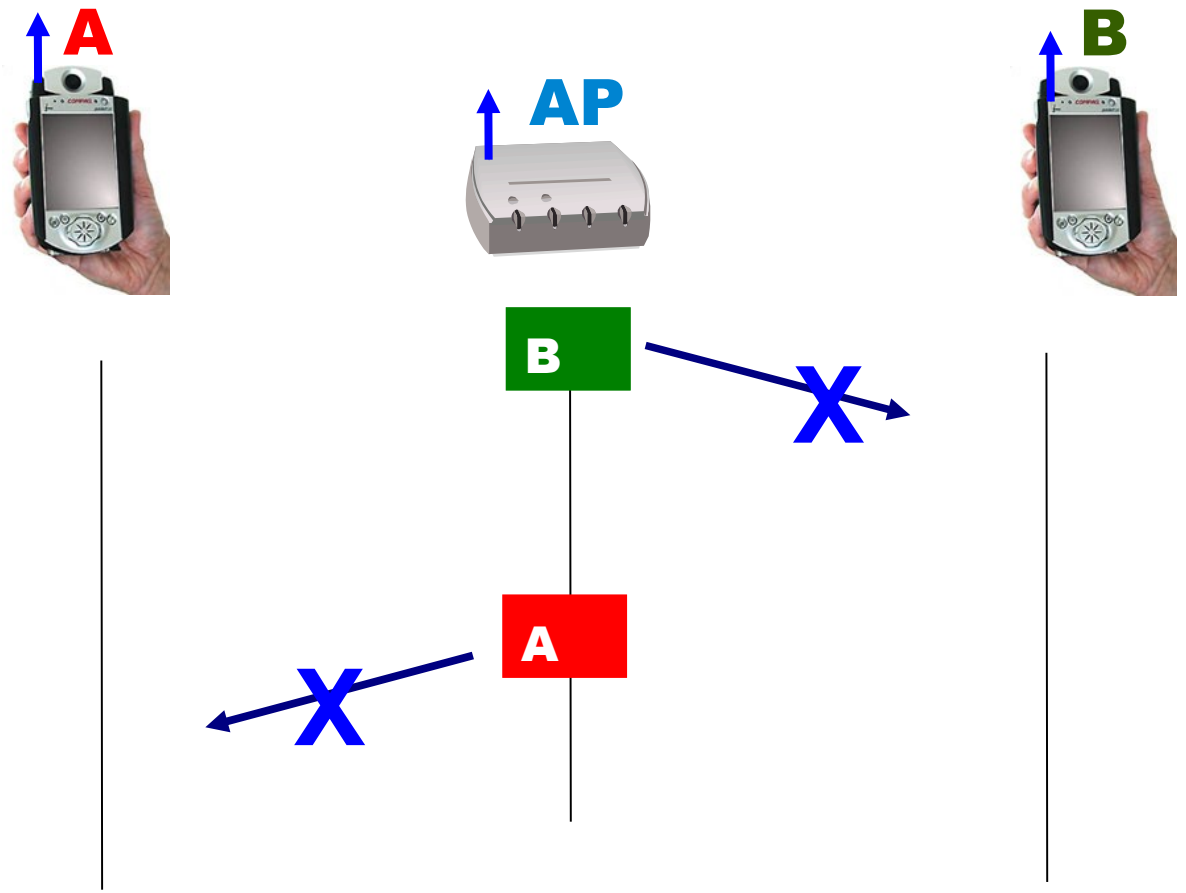
Inconsistent and poor performance

Frame Losses and Retransmissions



Frame Losses and Retransmissions

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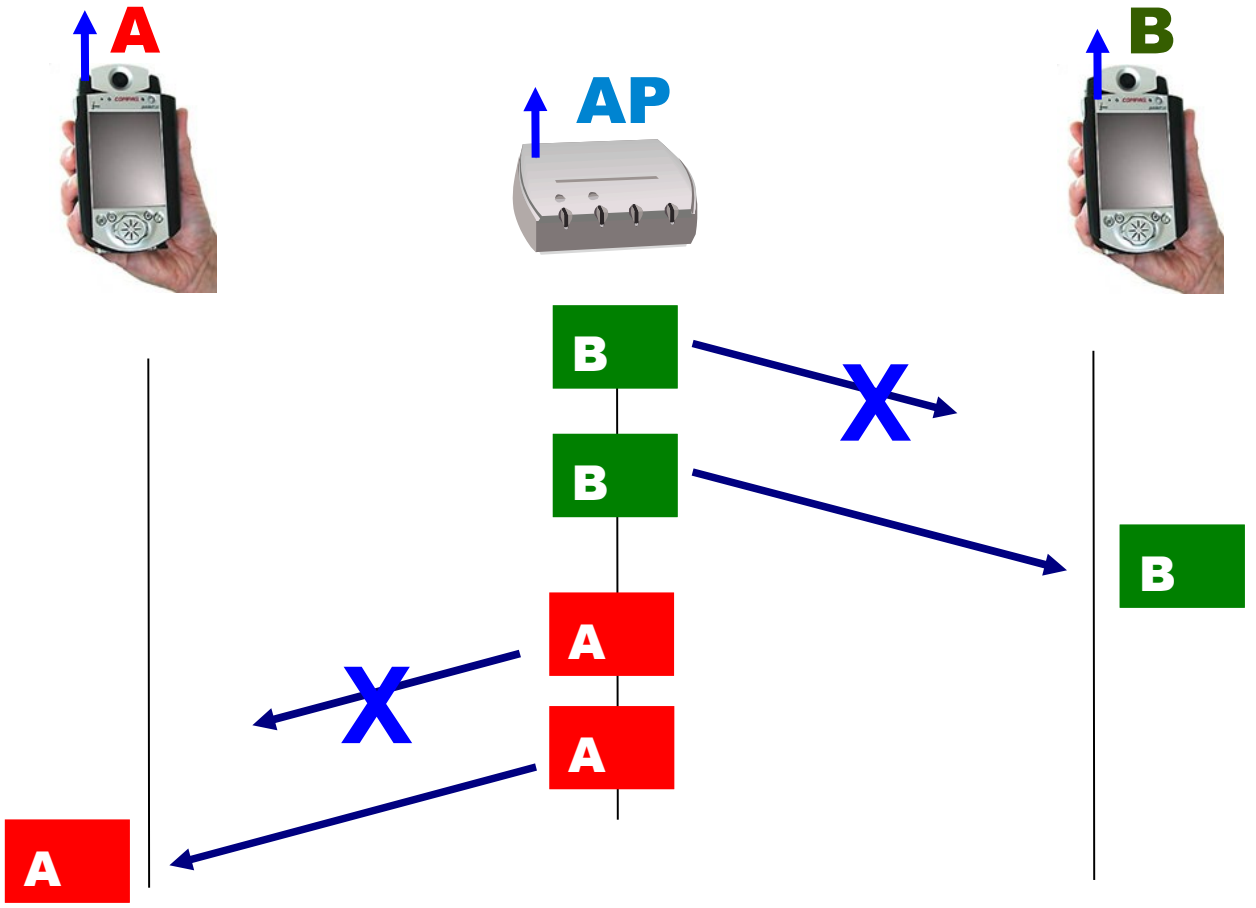

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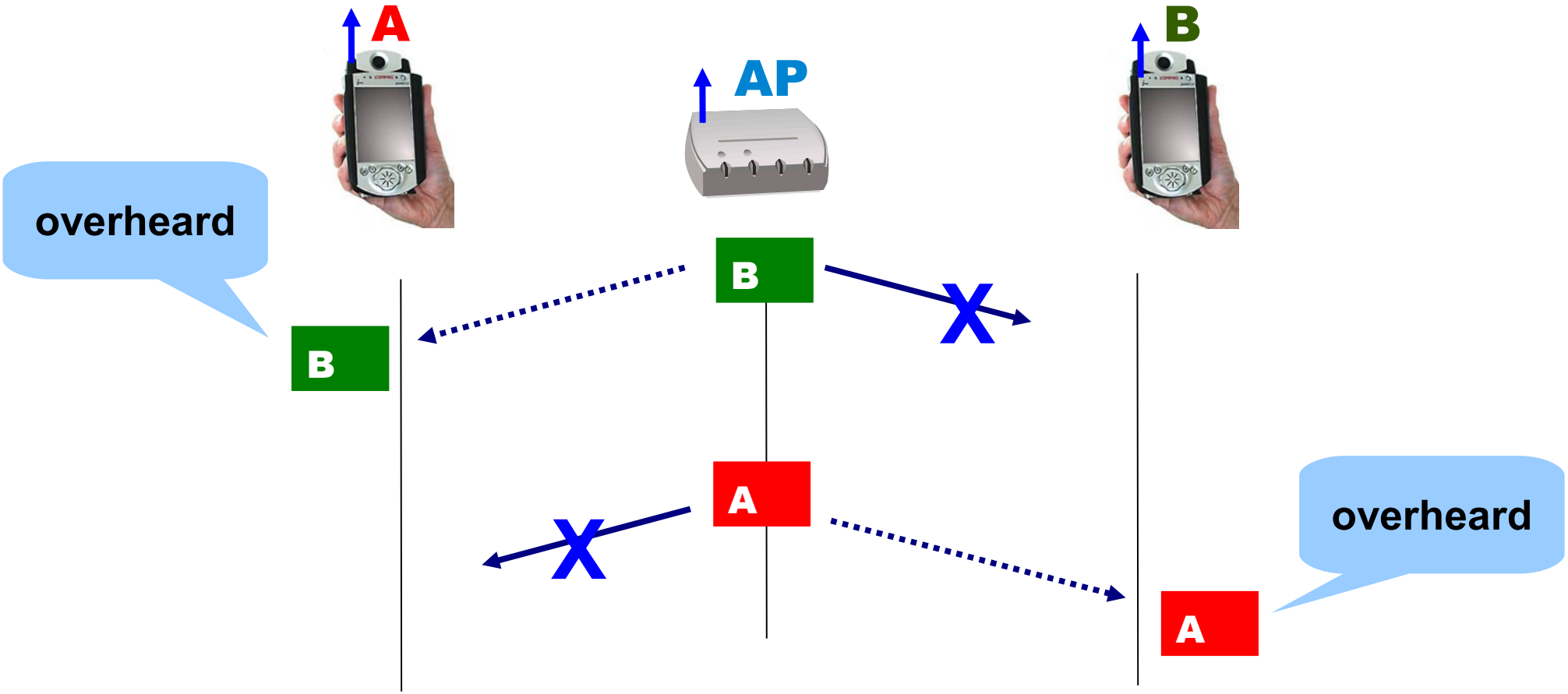
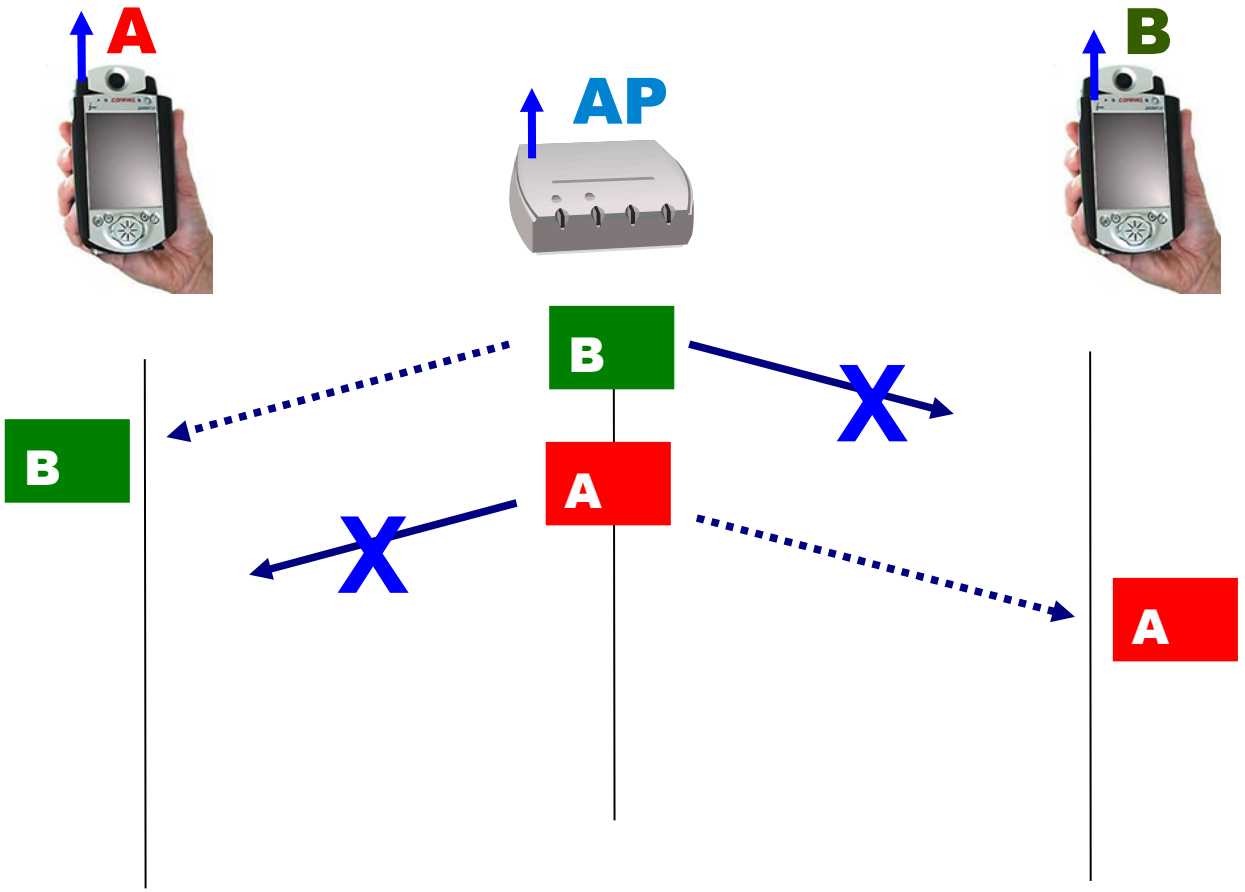


Network Coding Aided Retransmission



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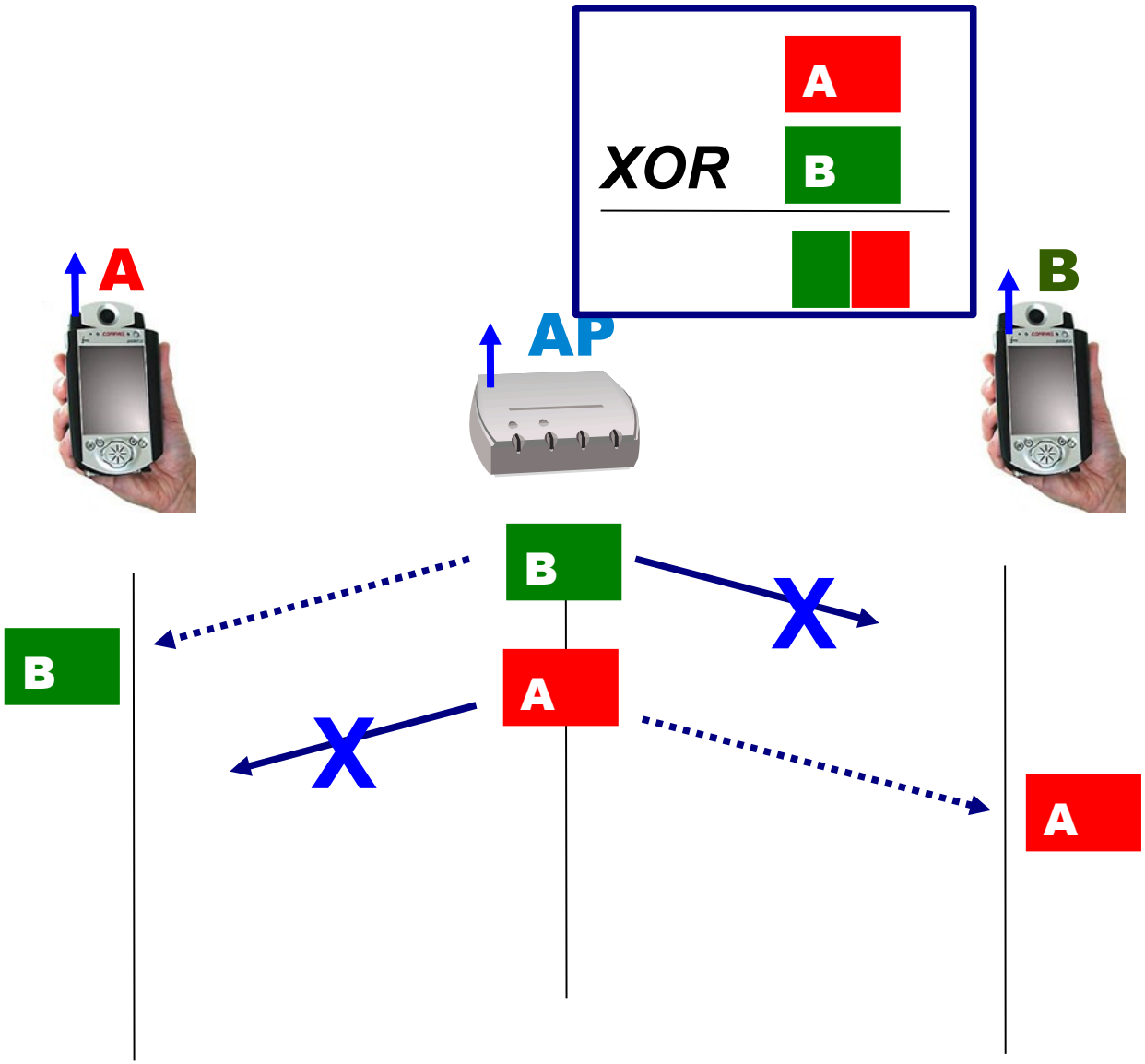

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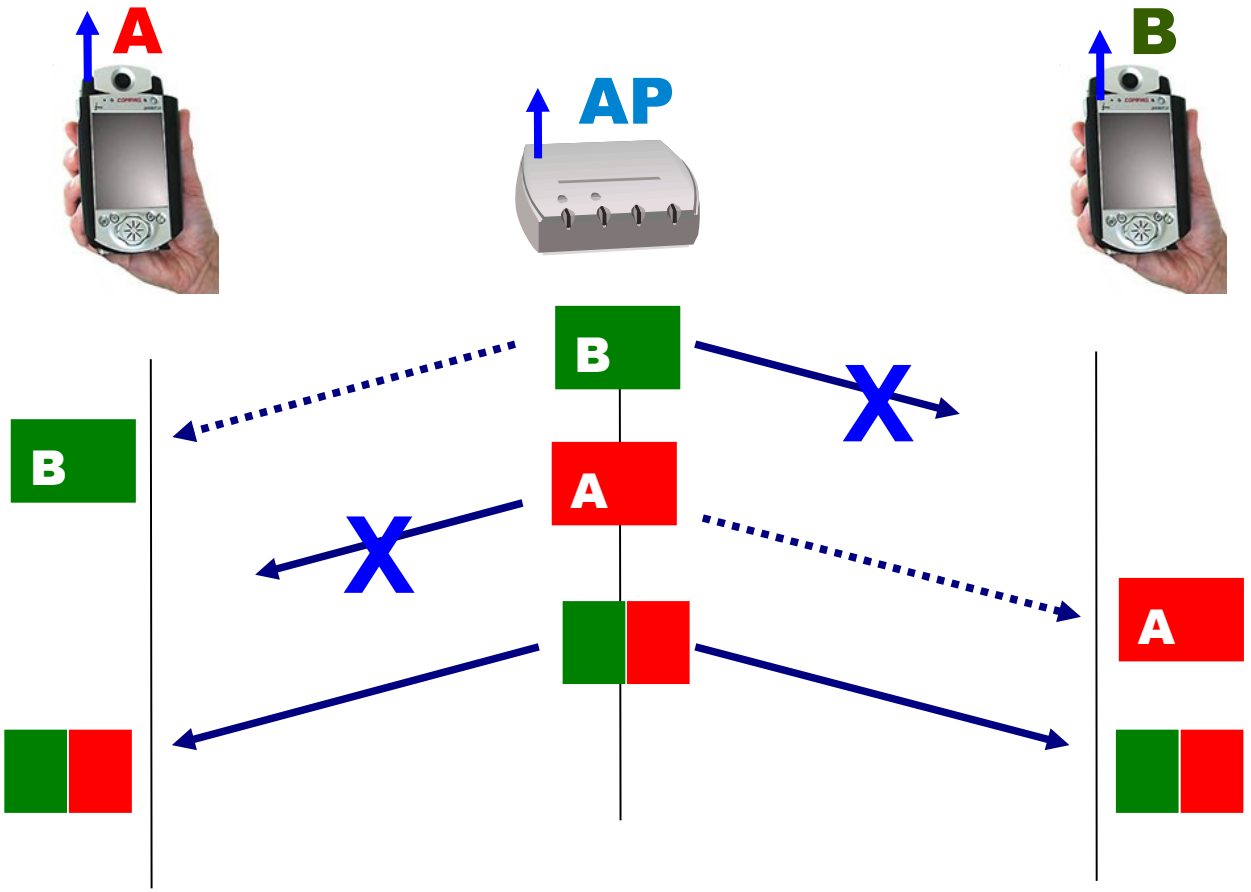

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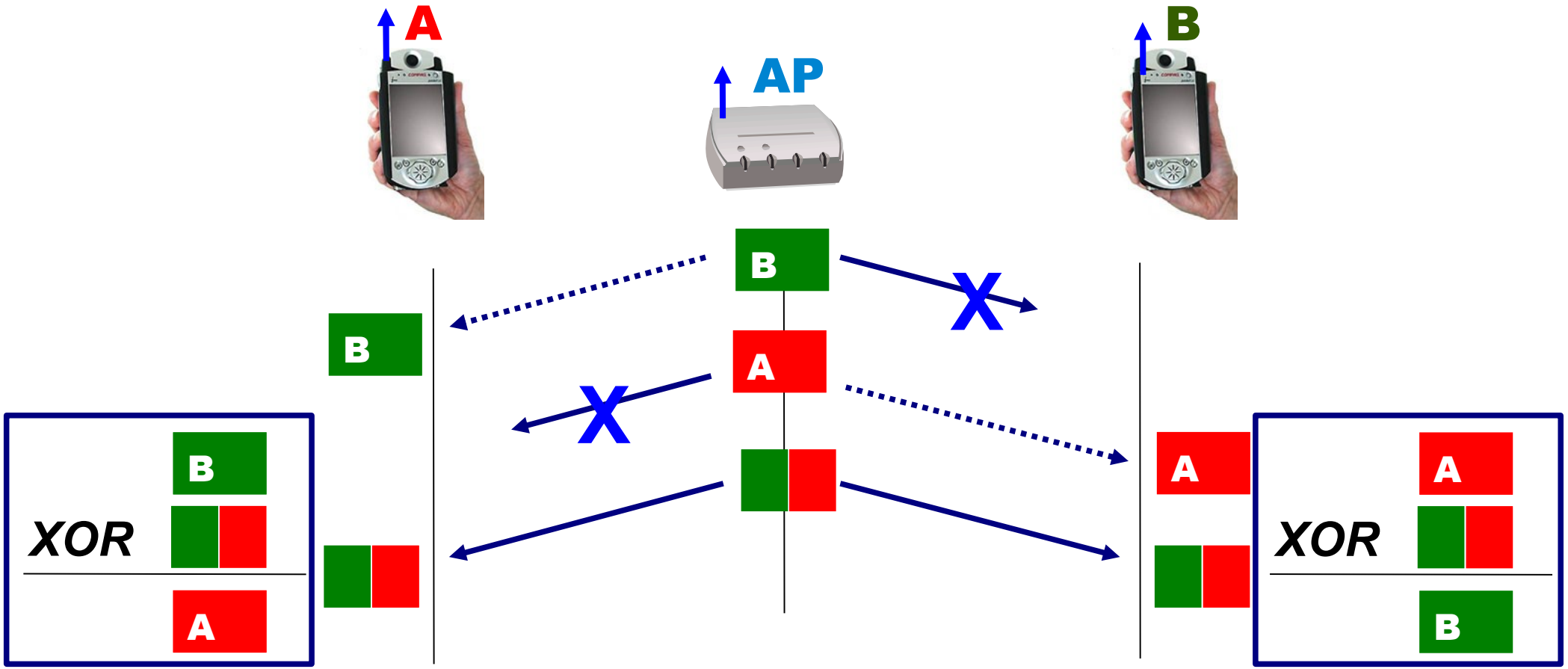

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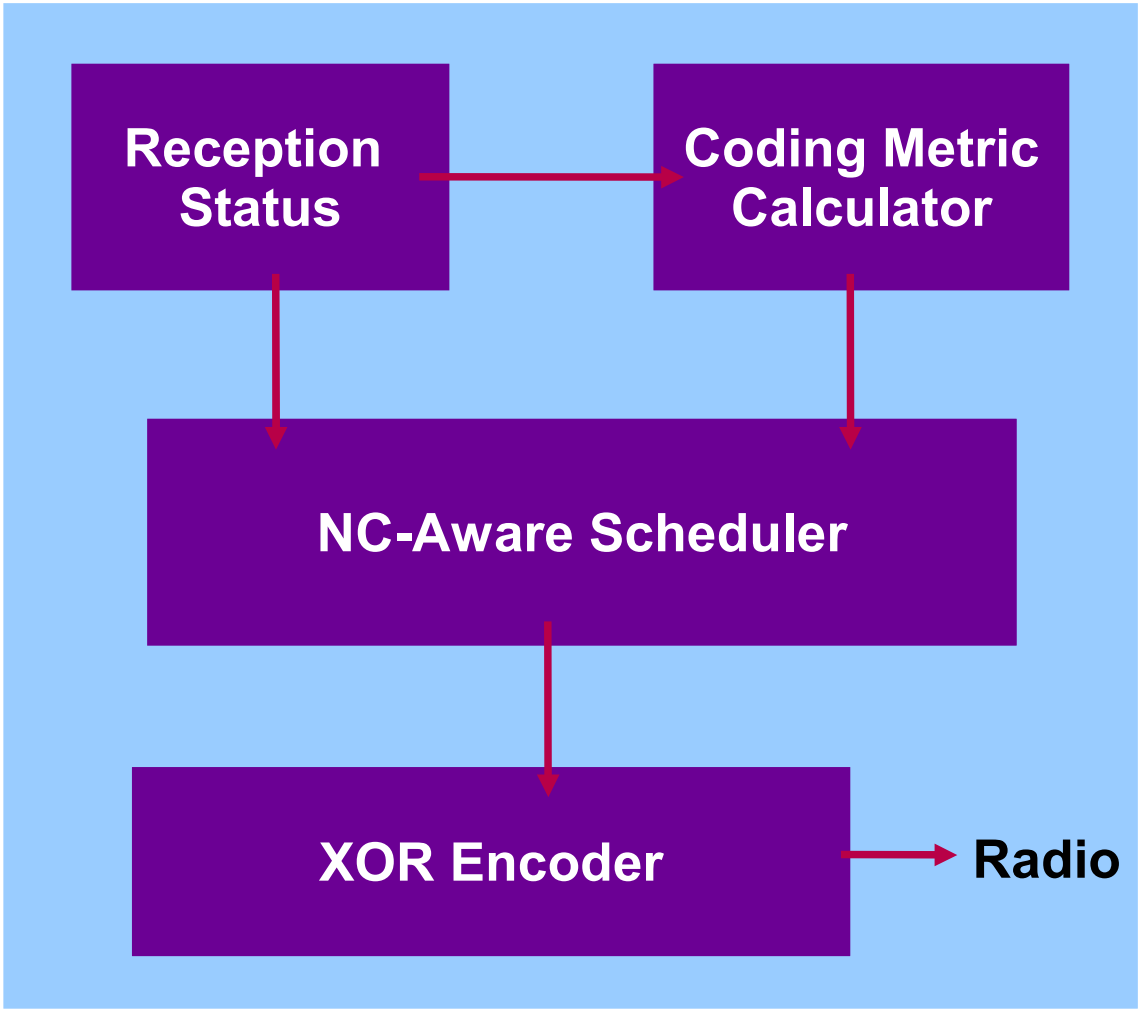
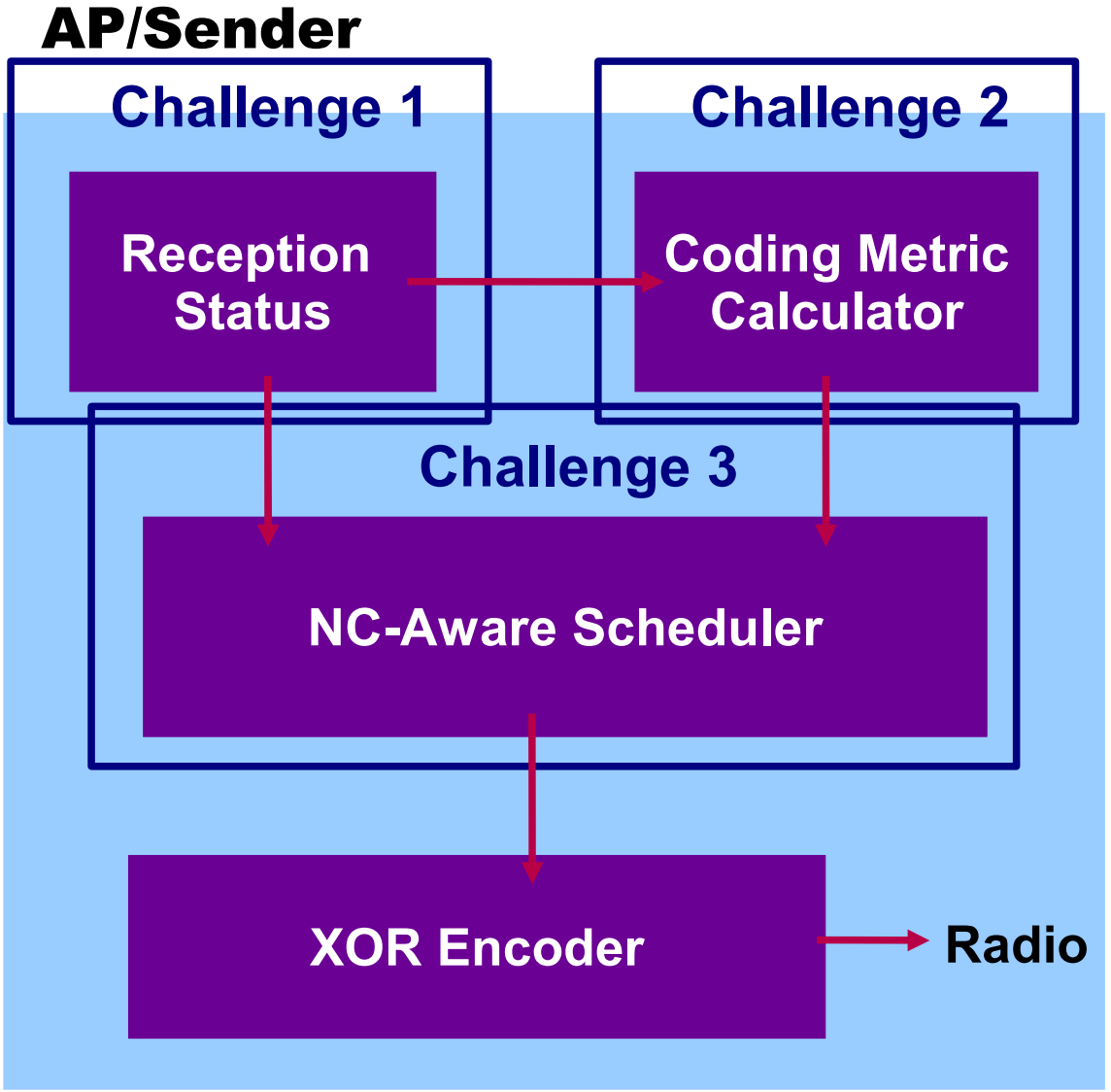
XORR Architecture

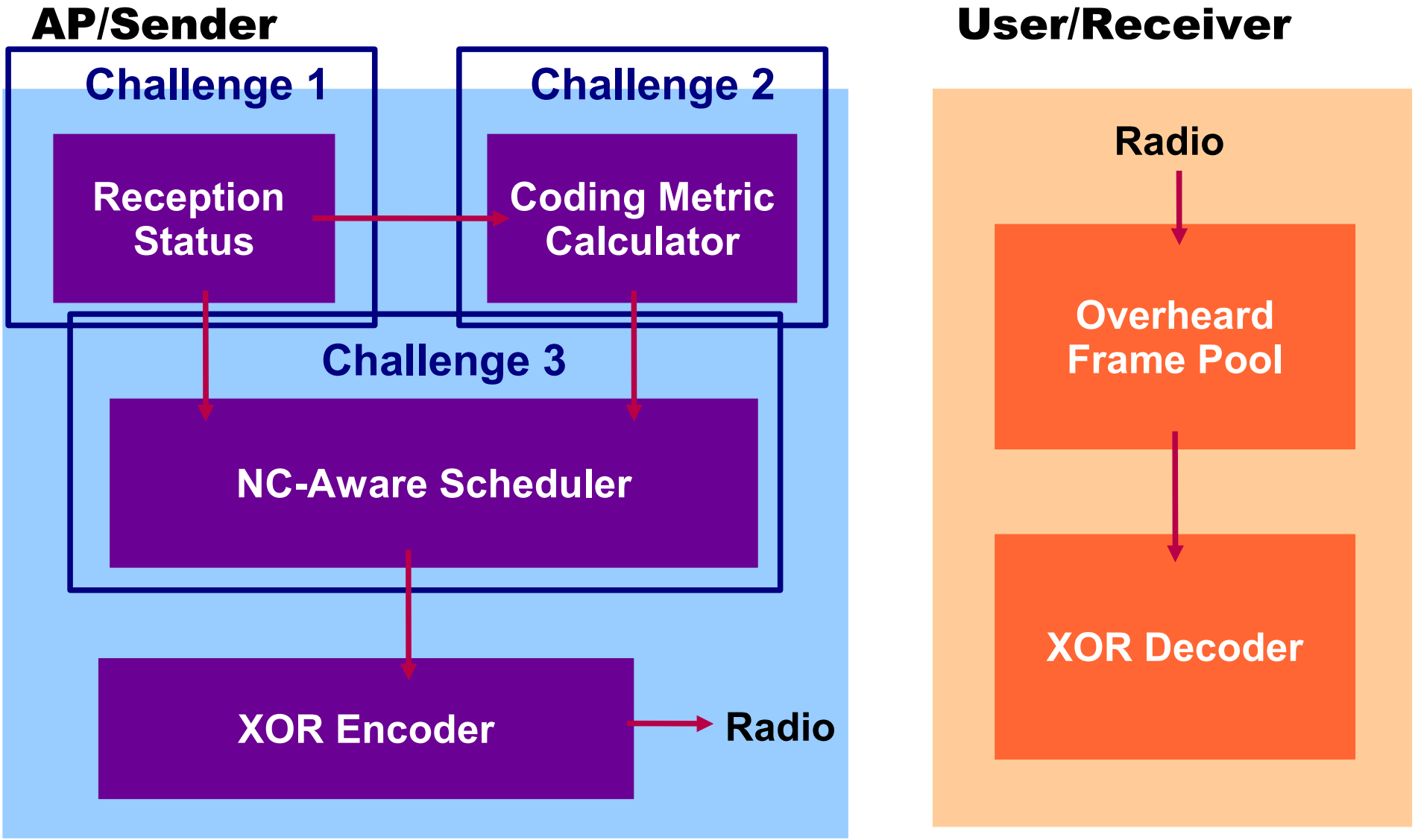
AP/Sender



XORR Architecture

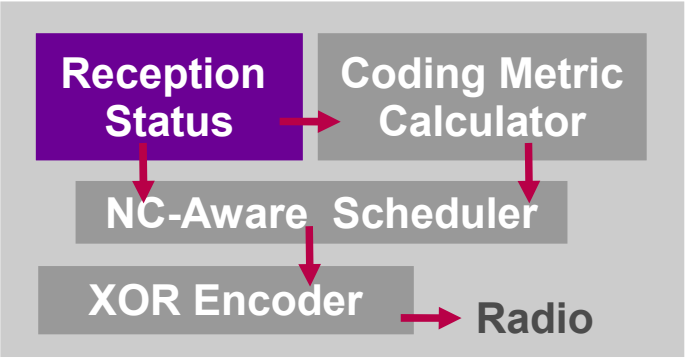


XORR Architecture



Challenge 1:

Reception Status



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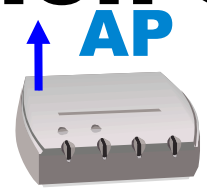
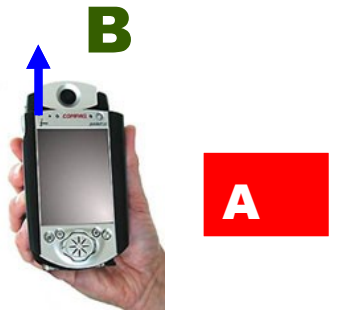
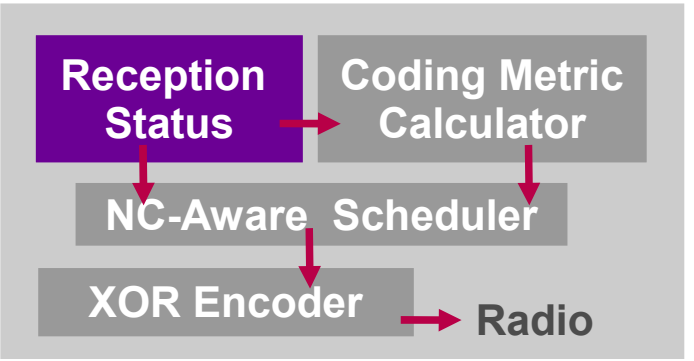


A *XOR* B =





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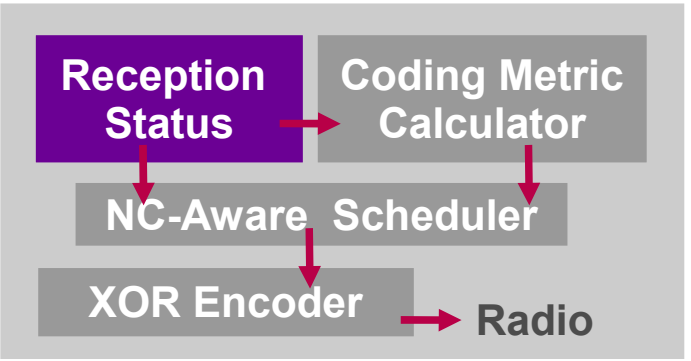
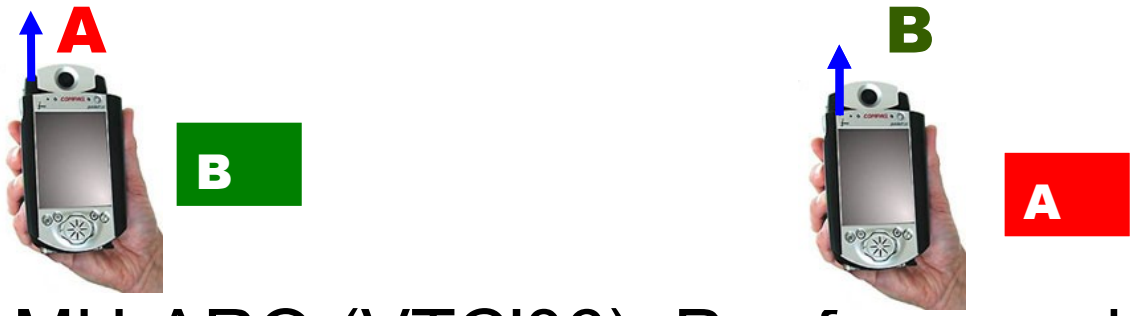
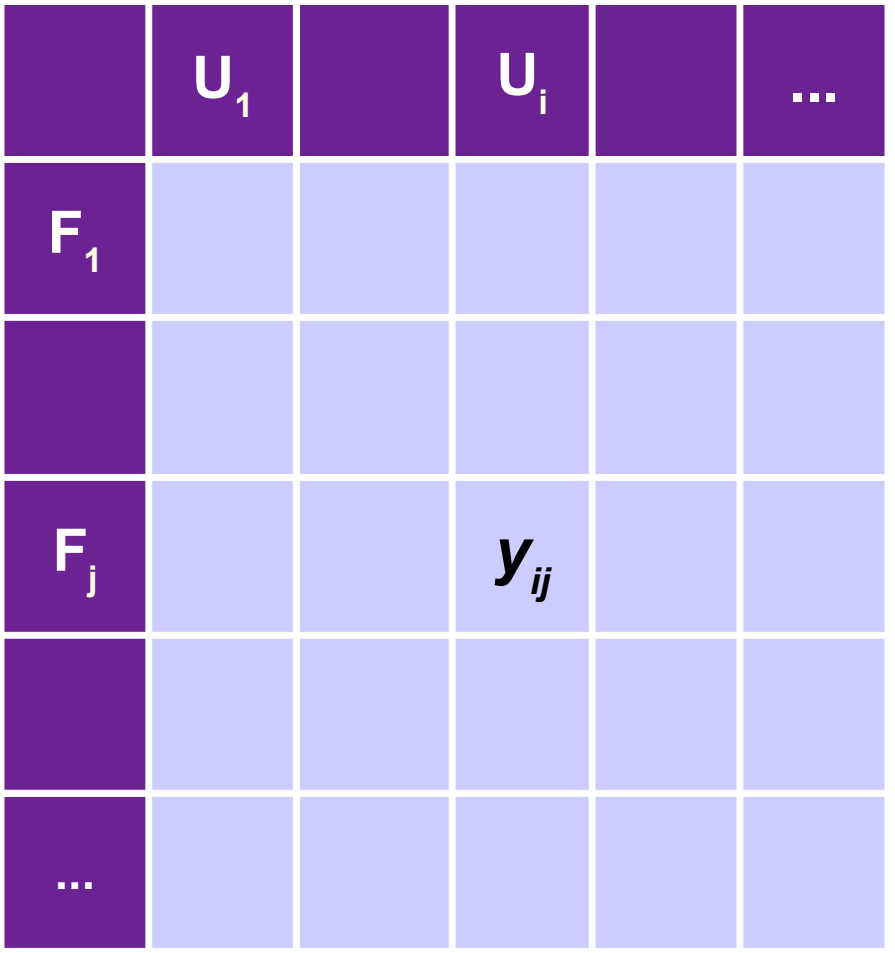




- MU-ARQ (VTC'06): Per-frame acknowledgement
  - ACK implosion
- ER (CoNext'07): Periodic reception report
  - Short period: signalling overheads
  - Long period: insufficient reception info

Solution 1: Reception Estimation

- AP maintains a reception table



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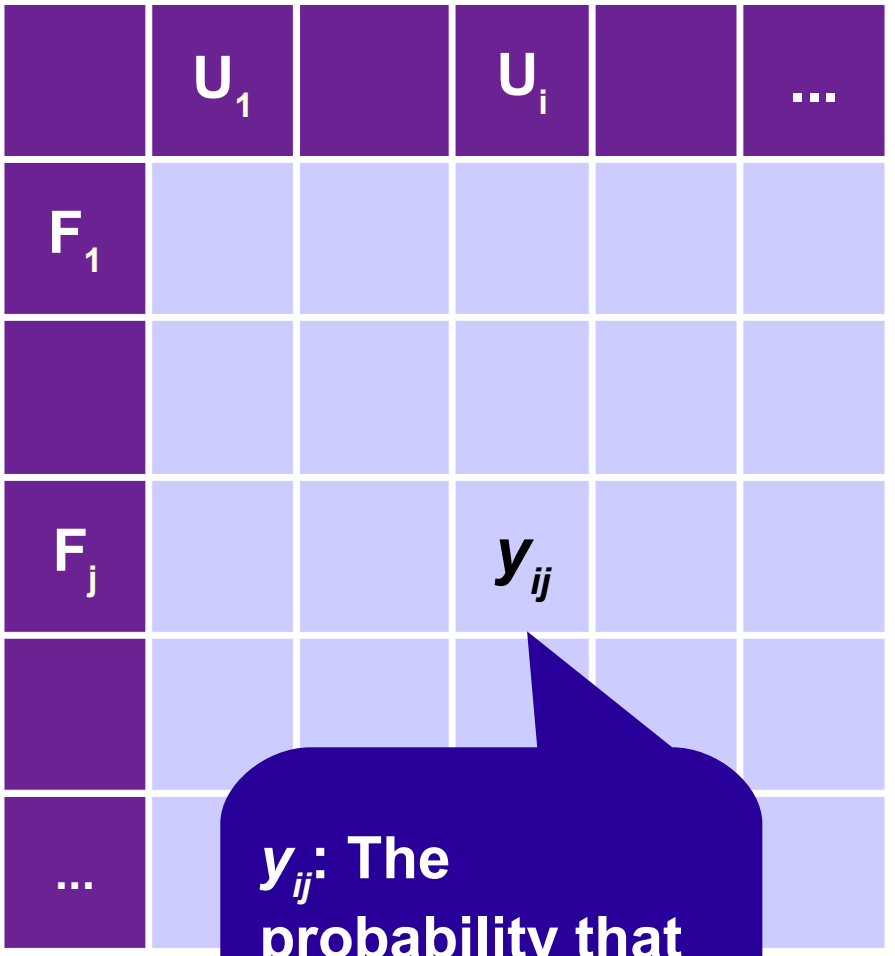
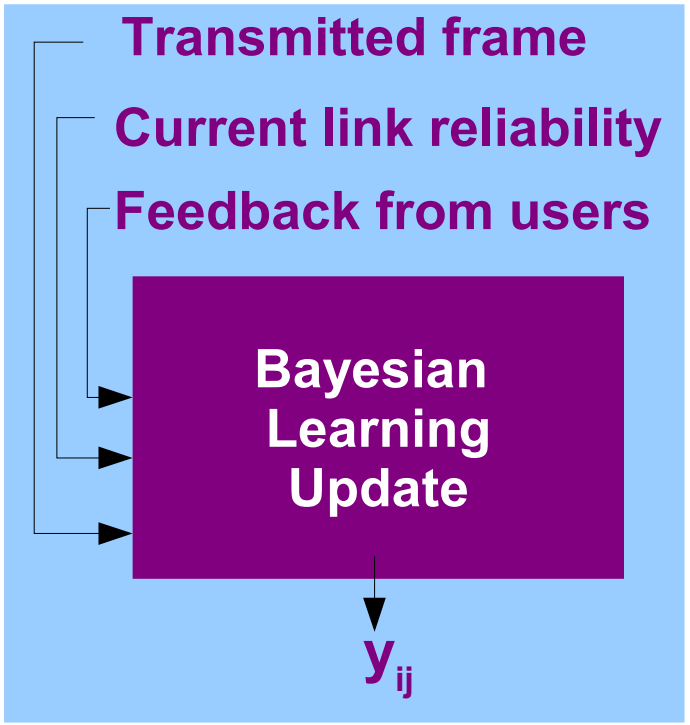


Solution 1: Reception Estimation

- AP maintains a reception table
- Table update

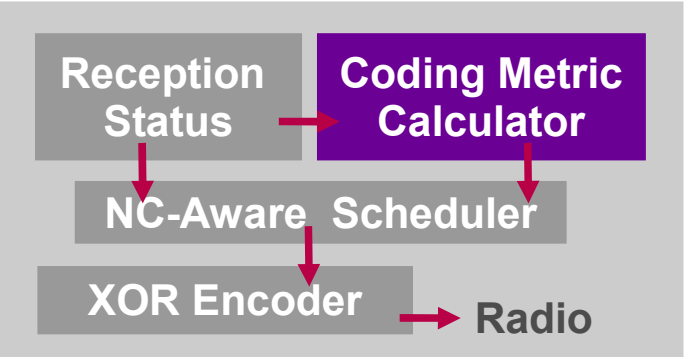


	U_1		U_i		...
F_1					
F_j			y_{ij}		
...					

y_{ij}: The probability that user u_i has the frame F_j

Challenge 2:

Coding Metric



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- MU-ARQ and ER: # of retrievals

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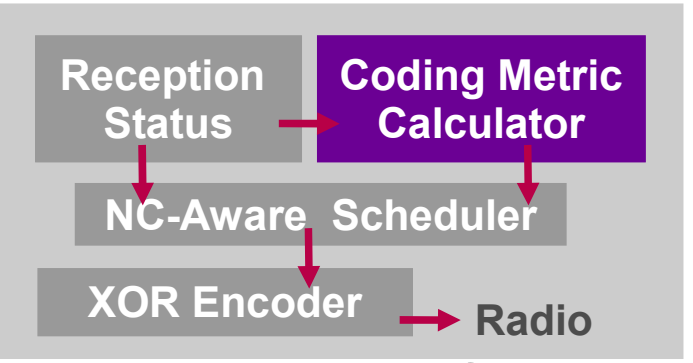

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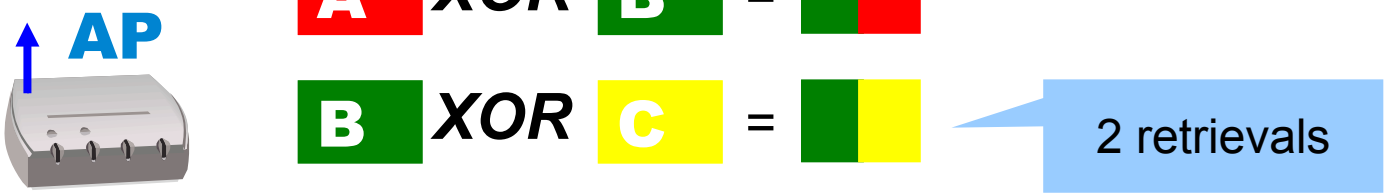

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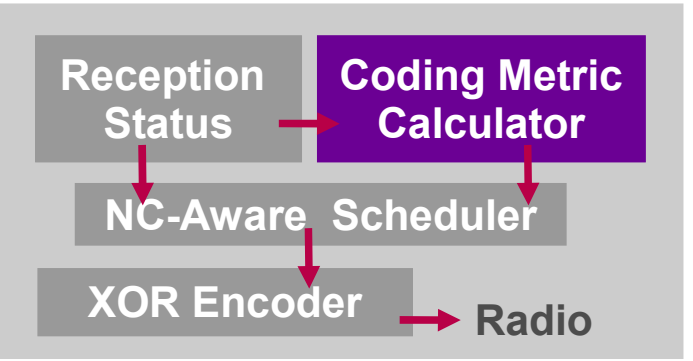
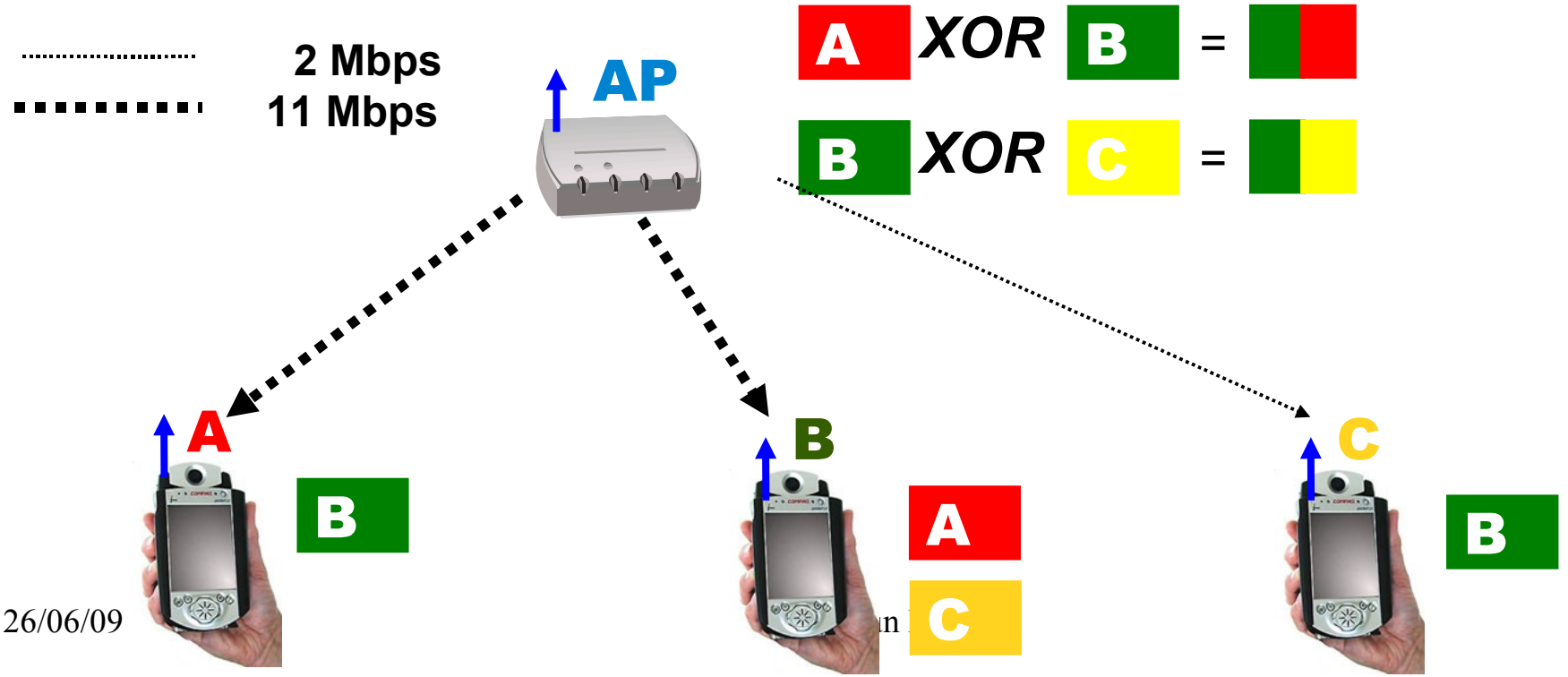


- Coding Metric: the measure of the coding benefit
- MU-ARQ and ER: # of retrievals
- Heterogeneous wireless link conditions, transmission rates and frame sizes



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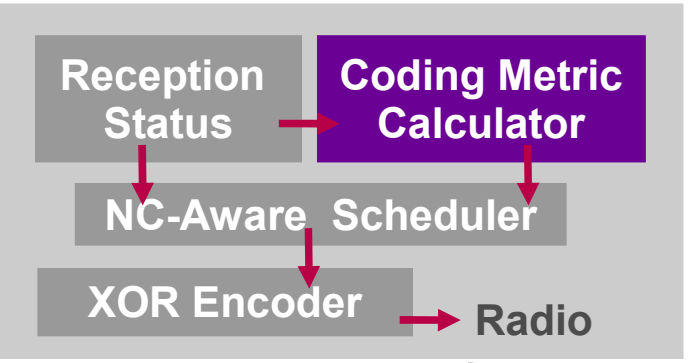

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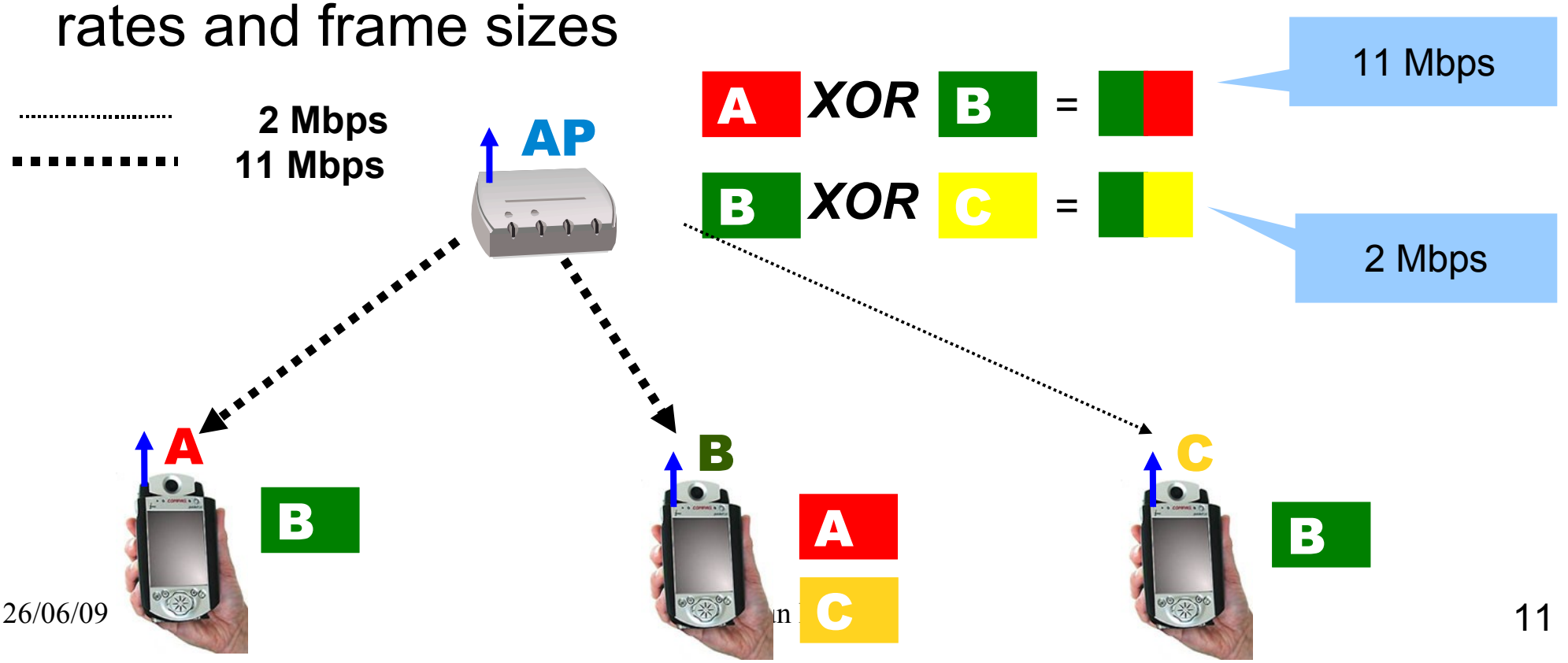

Solution 2:
Coding Metric- Expected Goodput

- Expected goodput
  - Estimated received throughput by transmitting a coded frame

$$X_g = \sum_i \frac{L_i}{L_g} R_g D_i$$

g: coded frame
i: frame index

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Frame Length

A: 1000 Bytes

B: 50 bytes

A⊕B: 1000 bytes

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Transmission Rate

A: 1000 Bytes

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A⊕B: 1000 bytes

R_A = 11 Mbps

R_B = 2 Mbps

$R_{A \oplus B}$ = 2 Mbps

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Transmission Rate

Decoding Probability

A: 1000 Bytes

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A⊕B: 1000 bytes

R_A = 11 Mbps

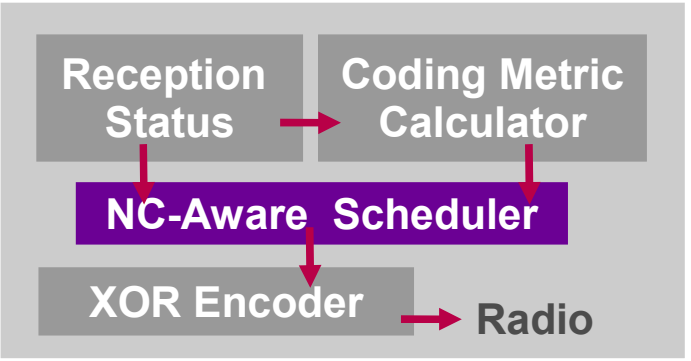
R_B = 2 Mbps

$R_{A \oplus B}$ = 2 Mbps

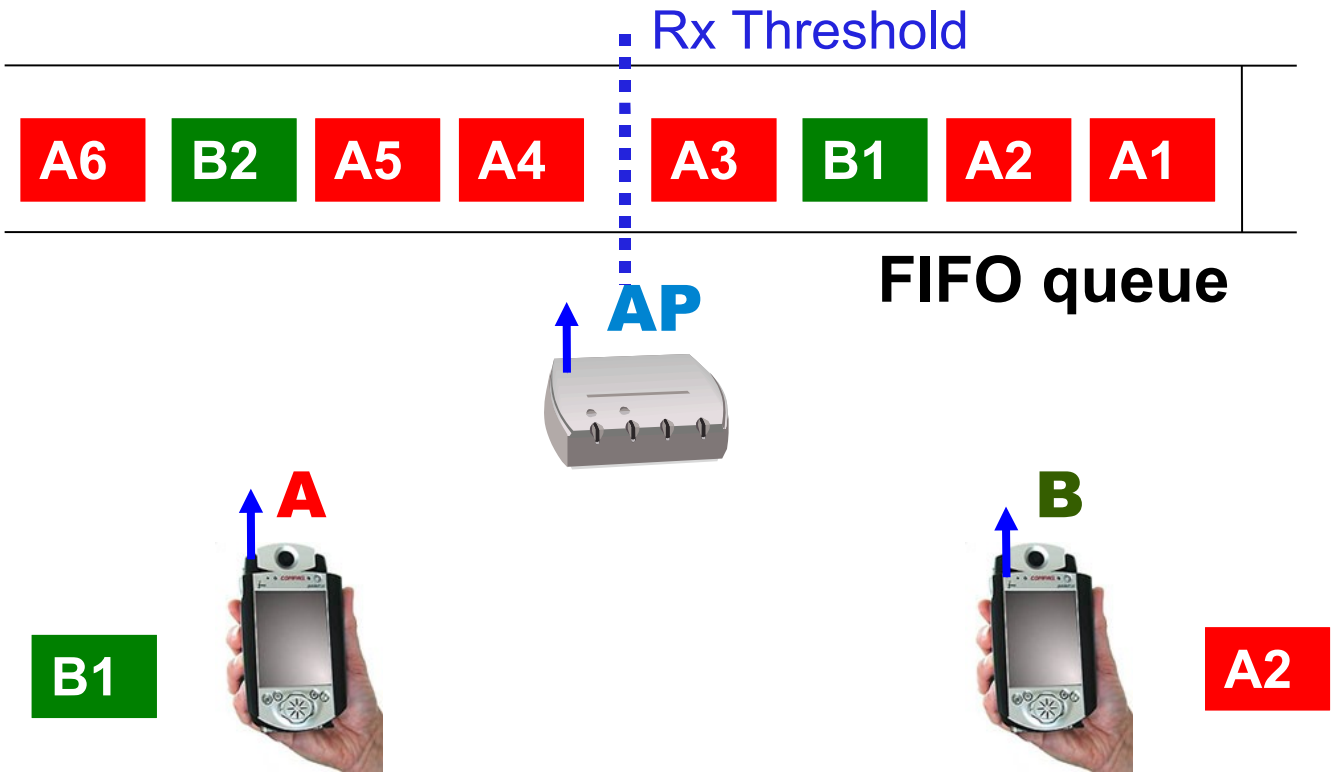
D_A = 100%

D_B = 100%

Challenge 3: NC-Aware Scheduling(1)



- ER (CoNext'07): FIFO queue with rx threshold



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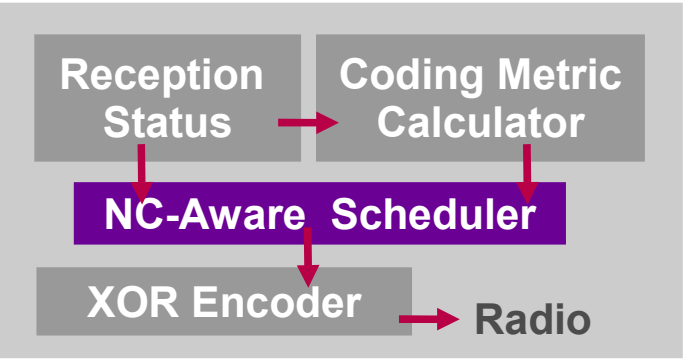

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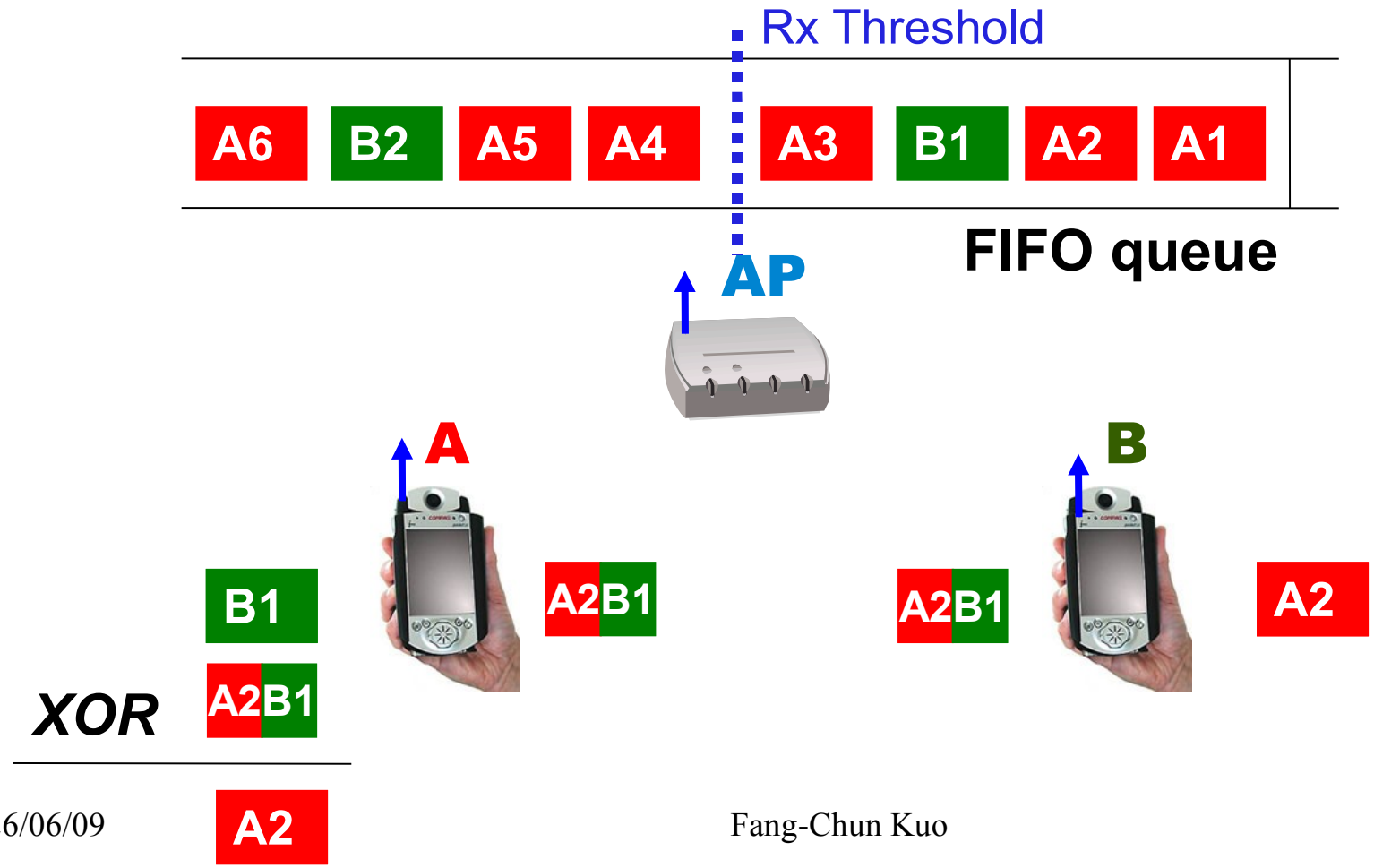

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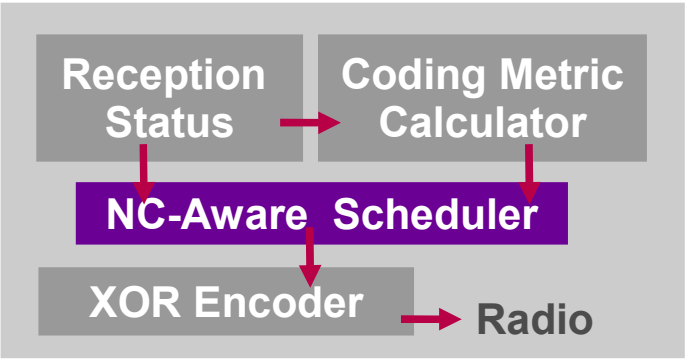

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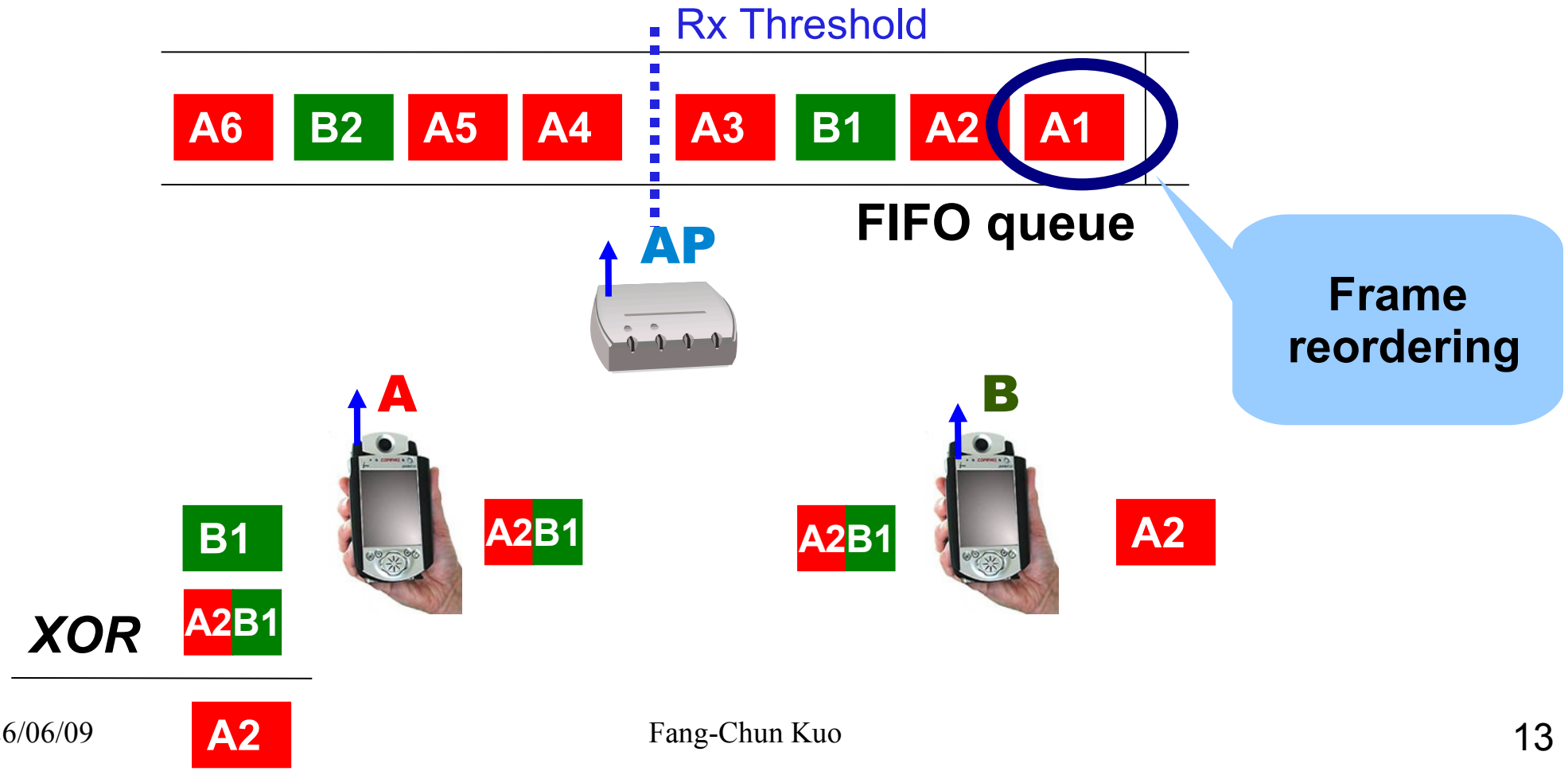
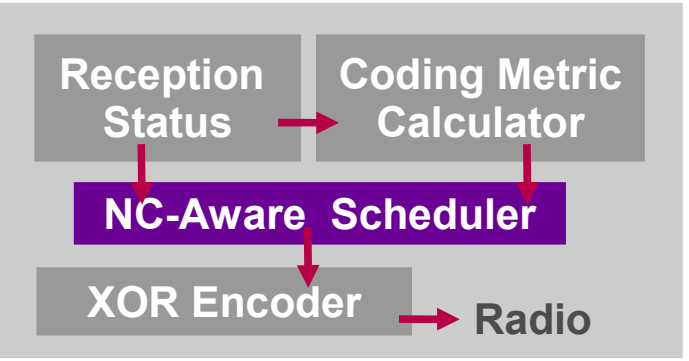
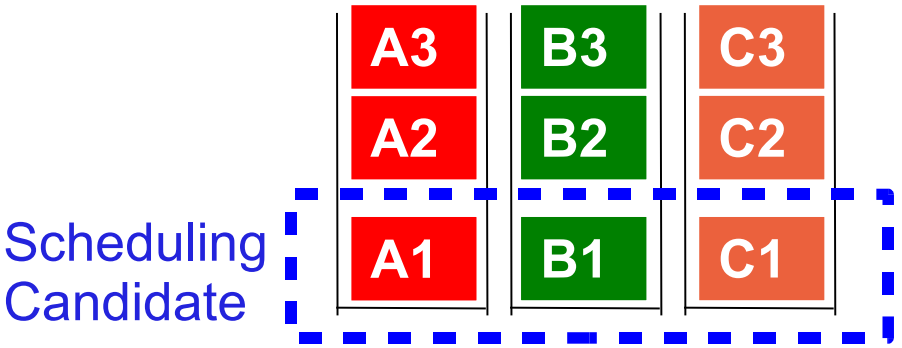
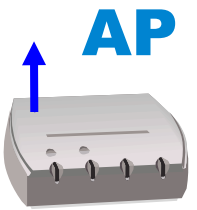


Challenge 3: NC-Aware Scheduling(2)



- NC-Aware Opportunistic scheduling
  - Opportunistically select a set of frames with maximal coding metric





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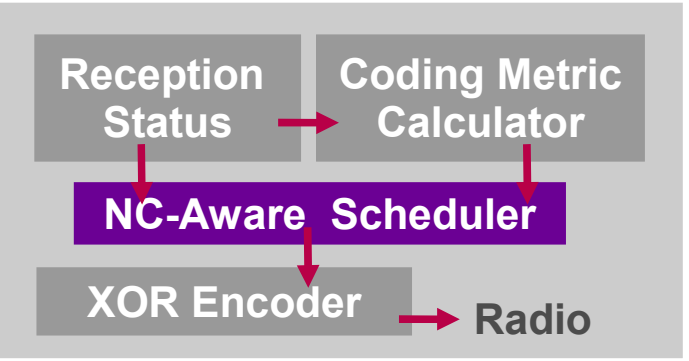

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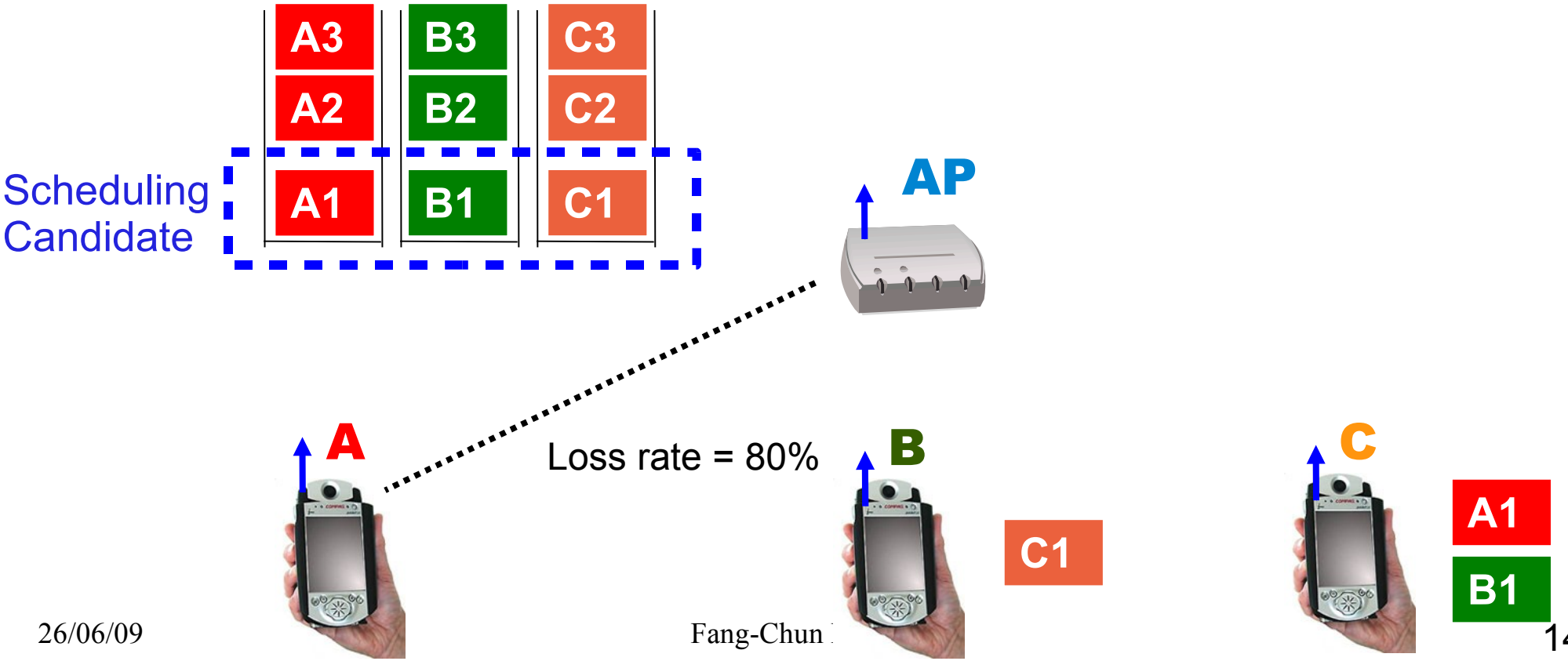

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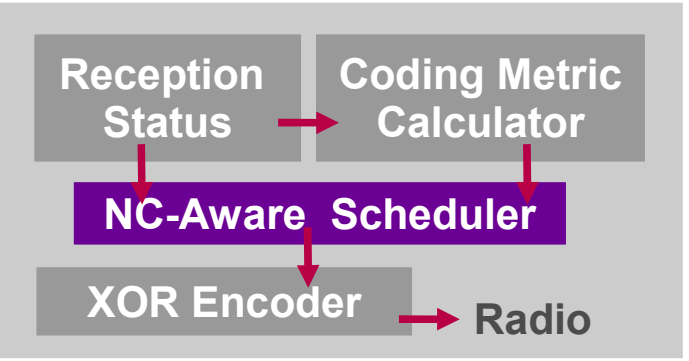

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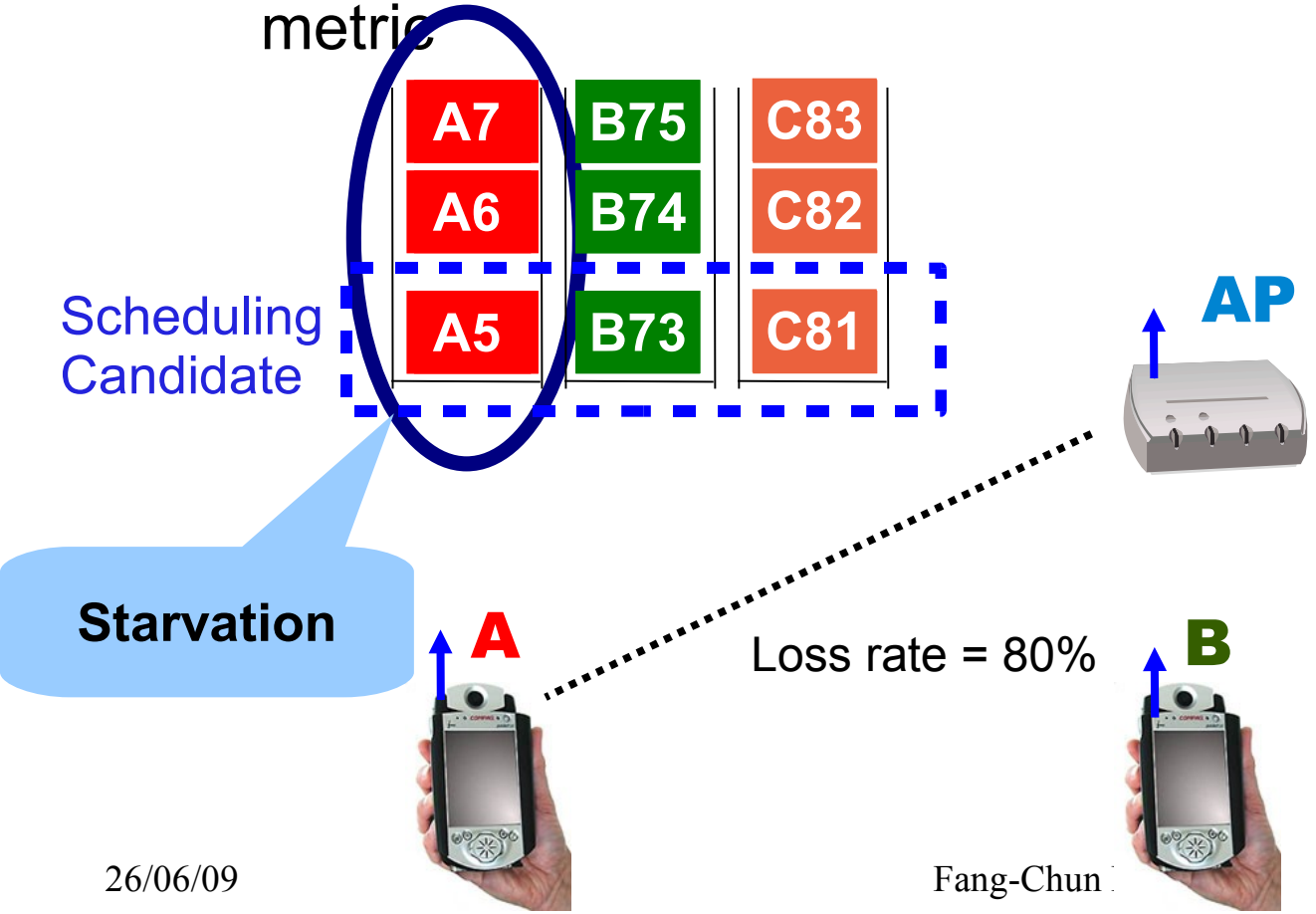
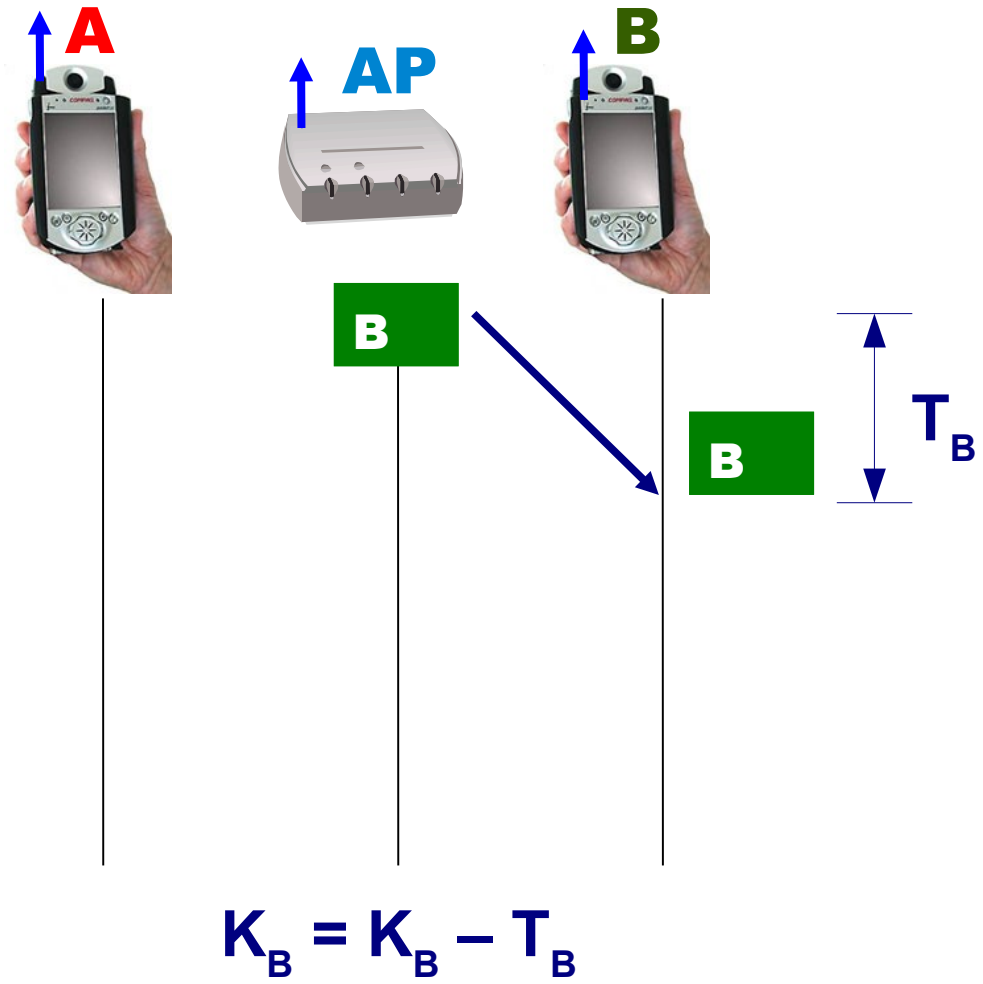


Solution 3:
NC-aware Credit-Based Fair Scheduling



- Credit
  - Available time for the AP to serve the user

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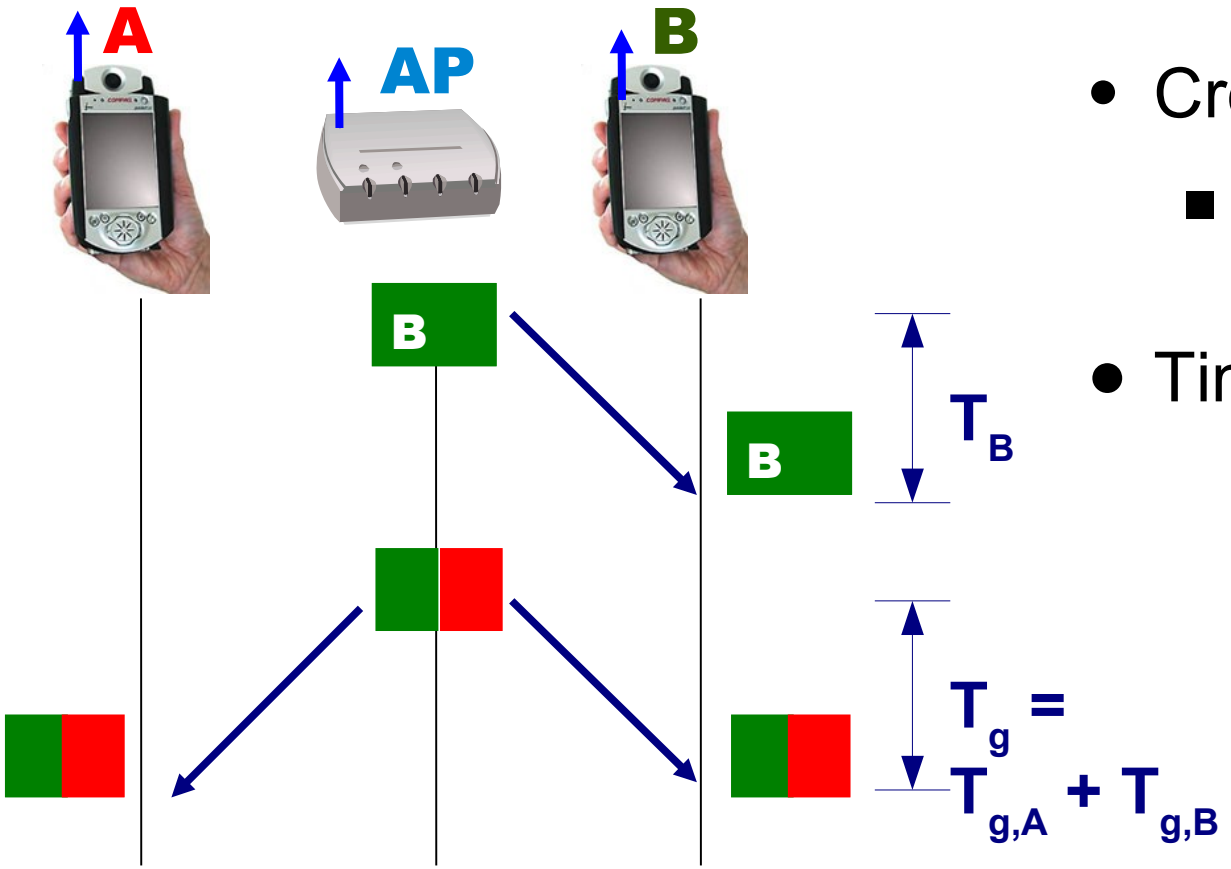
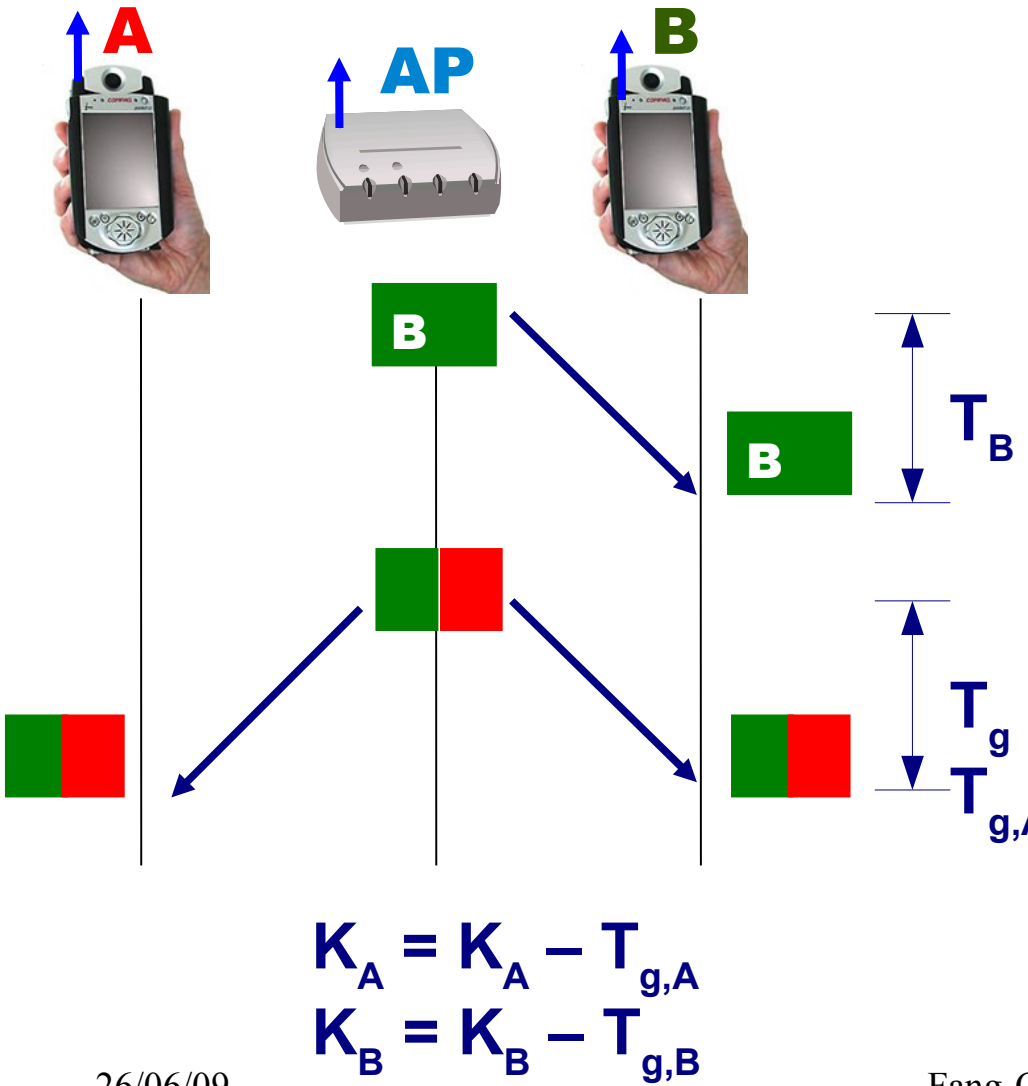


$K_A = K_A - T_{g,A}$

$K_B = K_B - T_{g,B}$

- Credit
  - Available time for the AP to serve the user
- Time assignment

Solution 3:
NC-aware Credit-Based Fair Scheduling



- Credit
  - Available time for the AP to serve the user
- Time assignment
  - Proportional to user's **coding advantage**
    - Decoding probability, D_i
    - Frame length
  - Improved performance for **ALL** users

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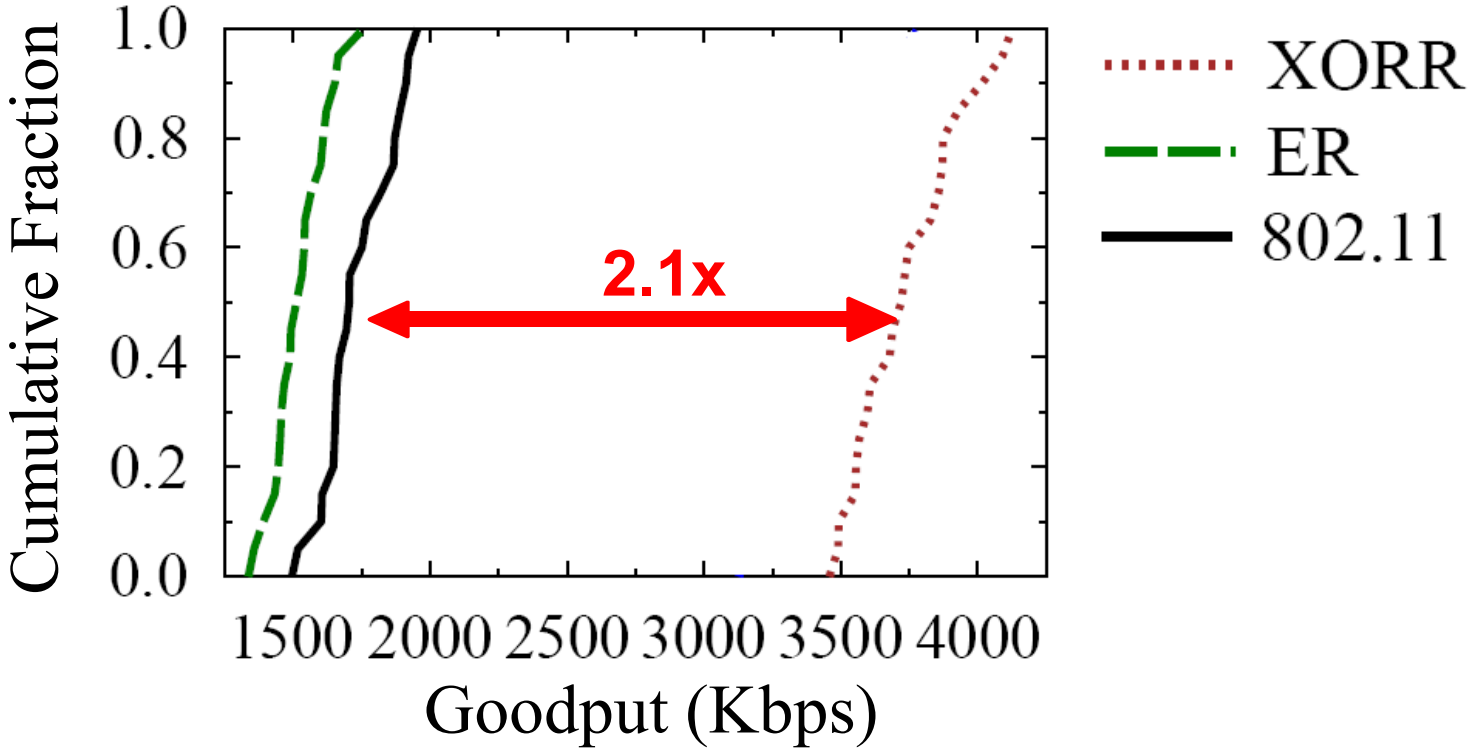
Simulation Setup

- Frame size = 1500 bytes
- Transmission rate: 1, 2, 5.5, 11 Mbps
- 10 users
- Benchmarks
  - 802.11
    - Traditional 802.11-based MAC retransmissions
  - ER
    - Another NC-aided retransmissions
    - Periodic reception report
    - Coding metric: only decoding ability

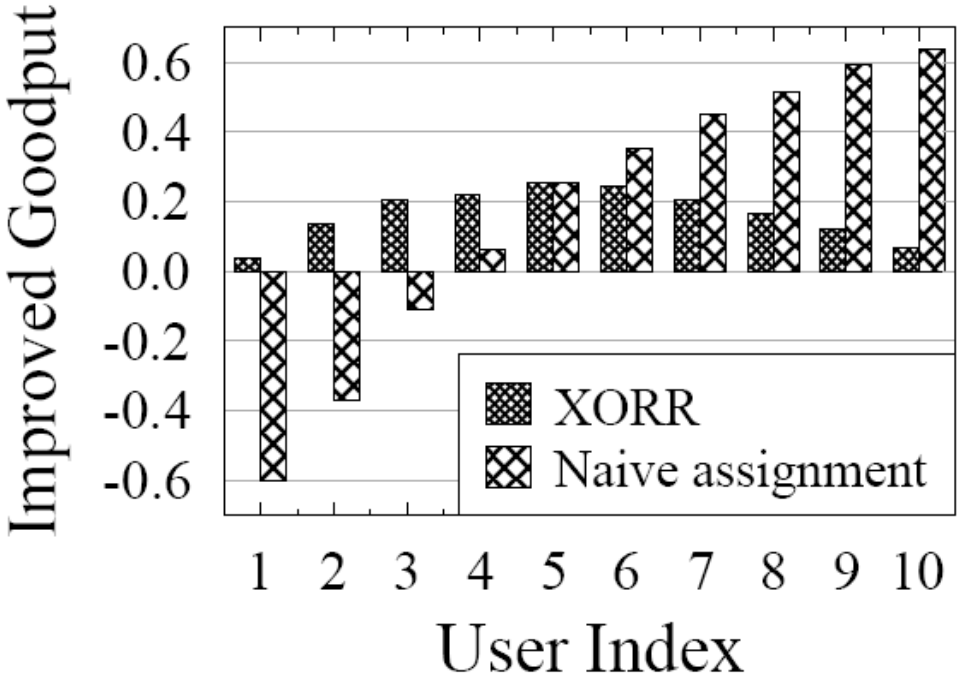
Time-Varying & Heterogeneous Links

- The varying speed of links: coherence time = 24.57 ms
  - corresponding to a fast walking speed (5 m/s)
- Link reliability varies from 0.3 to 0.7.



Time Assignment

- Compare with naïve equal time assignment
- Static and heterogeneous link
  - Link reliability is randomly chosen from 0.2 to 0.9
- User index is sorted by their link reliability.



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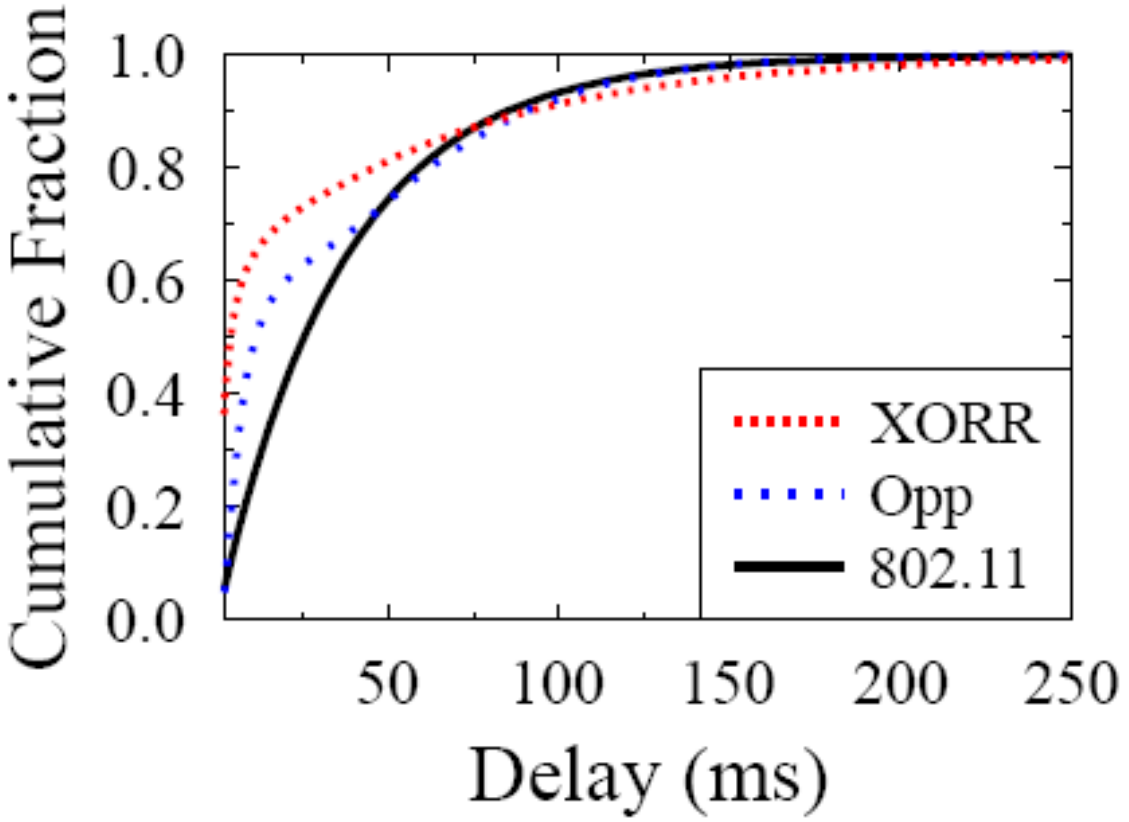
Conclusion

- XORR uses network coding to improve the retransmissions
- Contributions
  - Reception estimation
    - Use Bayesian learning update without extra signaling overheads
  - Coding metric: expected goodput
    - Decoding ability, transmission rate and frame length
  - NC-aware fair scheduling
    - Ensure improved performance for ALL users
    - Maintain time fairness
- XORR outperforms 802.11 and other NC-aided retransmission scheme

Q & A

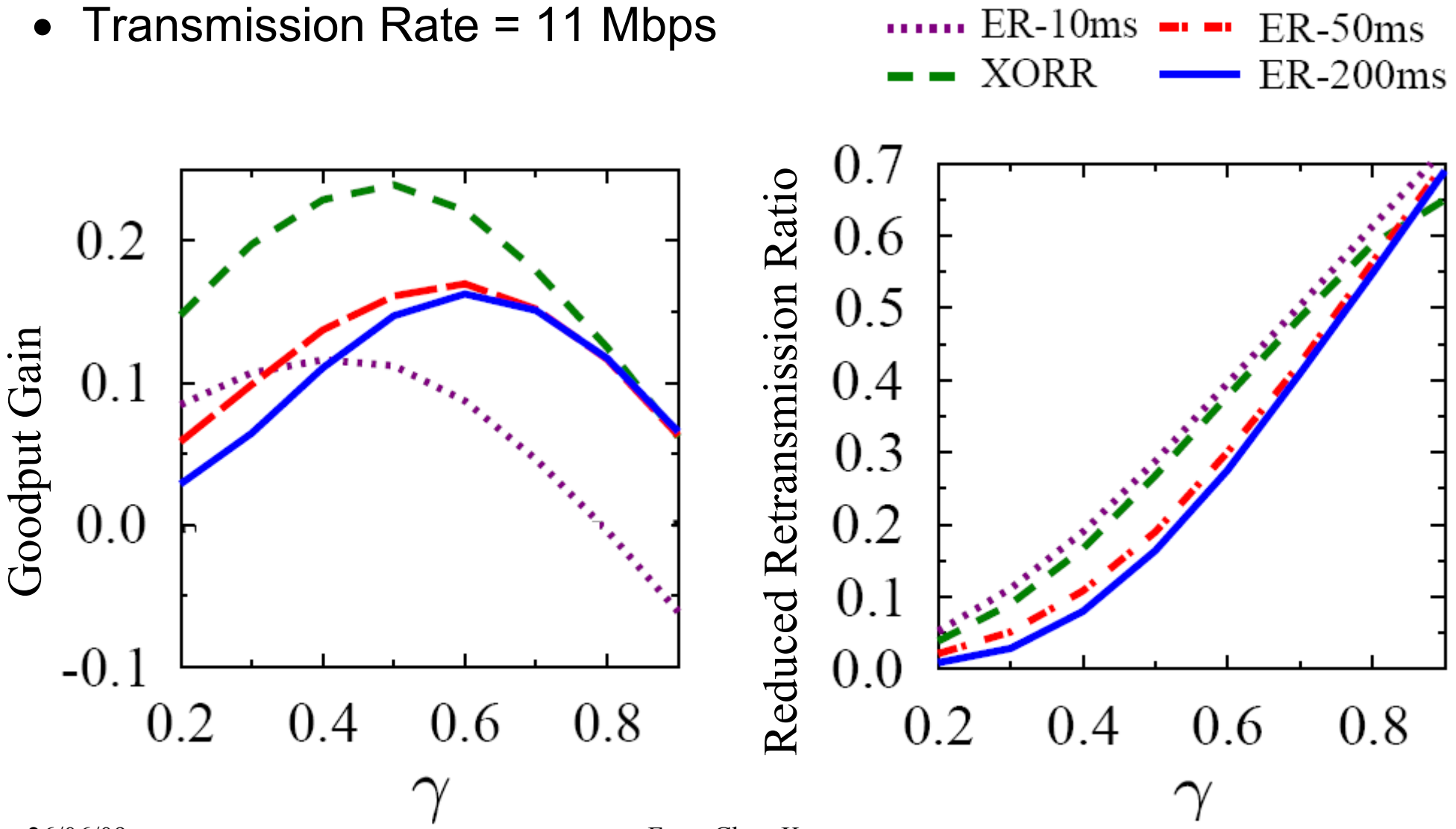
Impact on Transmission

- 10 users
- Time-varying channel
  - Coherence time = 24.57 ms (corresponding to a fast walking speed (5 m/s))
  - Link reliability varies from 0.4 to 0.8.



Static Channel
Homogeneous Links

- 10 users
- Transmission Rate = 11 Mbps



Link Measurement Error

- Measured link reliability = link reliability + error
- Time-varying and heterogeneous links
  - Coherence time = 6.14 ms (mobile speed = 20 m/s)
  - Link reliability varies from 0.3 to 0.7.