Retransmission diversity: an entropic view of conflict resolution and resource allocation

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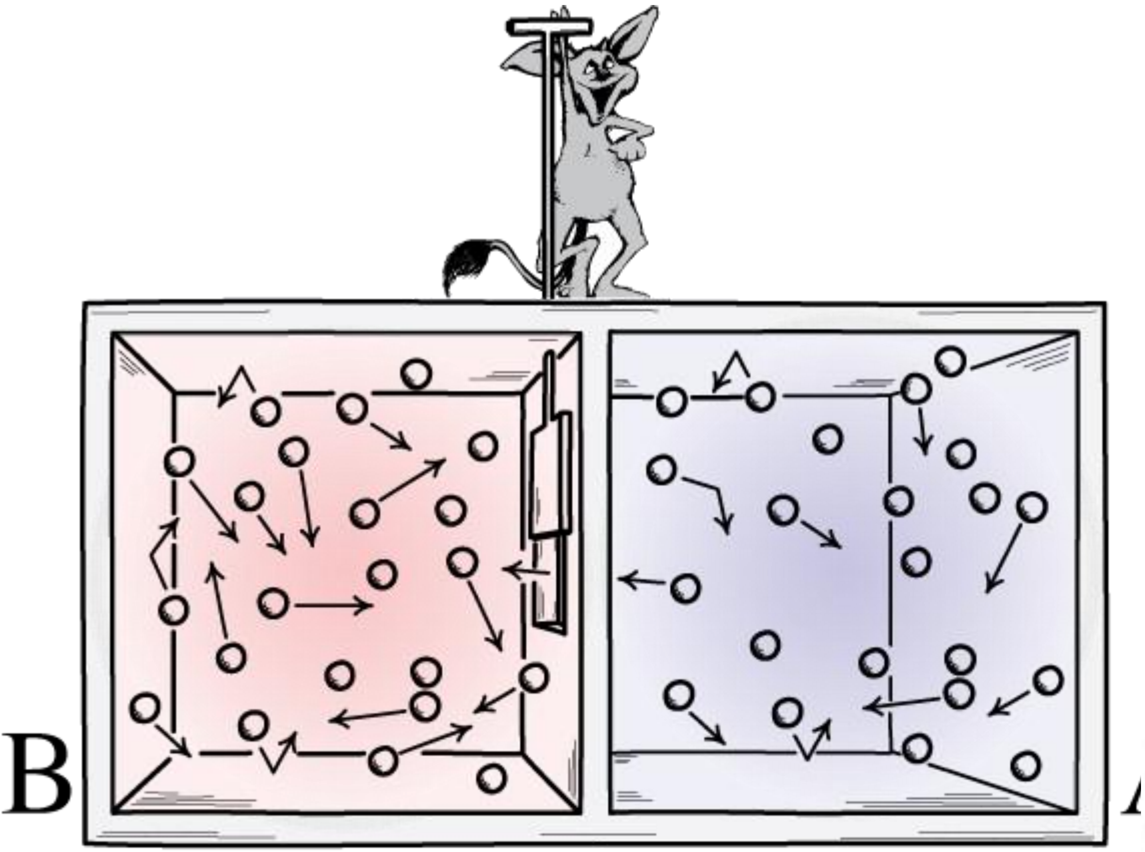
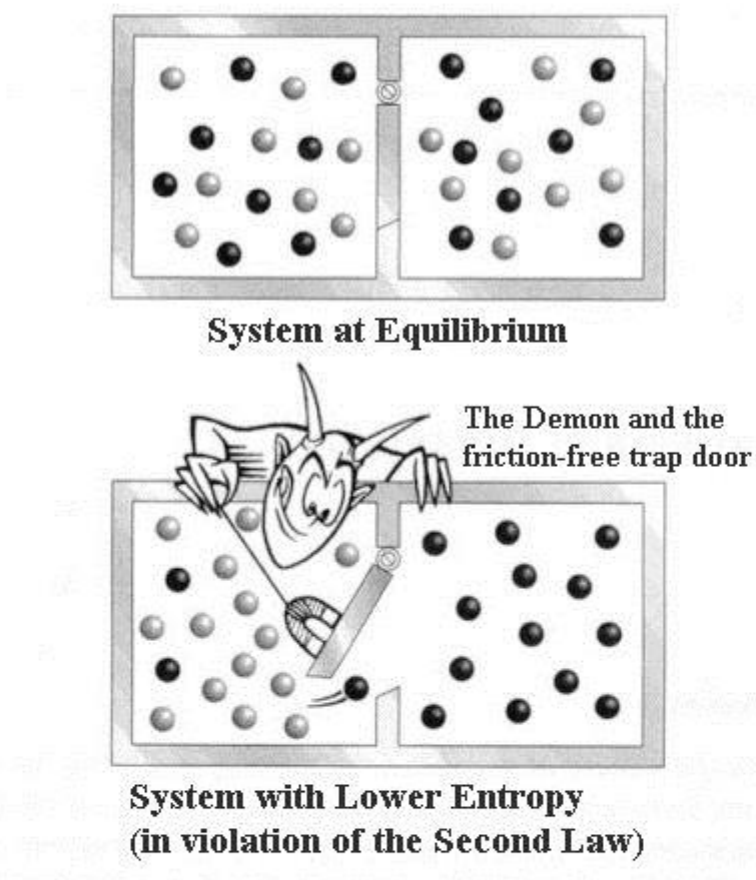
Maxwell’s demon problem

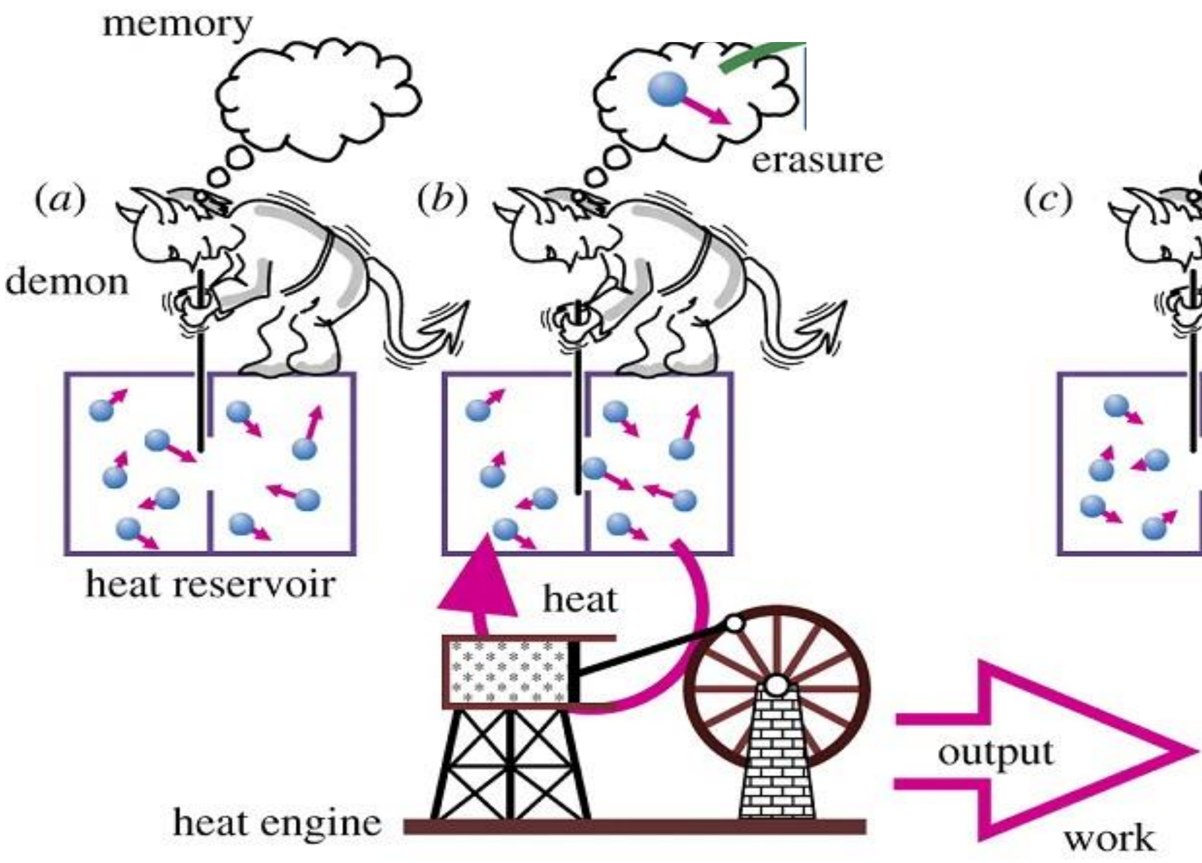
- Proposed in 1867 by James Clerk Maxwell
- Operation of the demon challenges second law of thermodynamics
- 100 years before a reasonable explanation was proposed
- Operation of the demon creates a sudden increase of temperature by a simple measurement of information
- Link between thermodynamics and information theory

Maxwell's demon problem





Information erasure



Maxwell`s demon problem conclusions (so far)

- Information erasure is the fundamental irreversible process that creates entropy and balances out the operation of the demon.
- Erasure can not be avoided
- However for engineers the lesson is to avoid erasure as much as possible or to exploit information (as the demon does) as much as possible before discarding or erasing it from memory

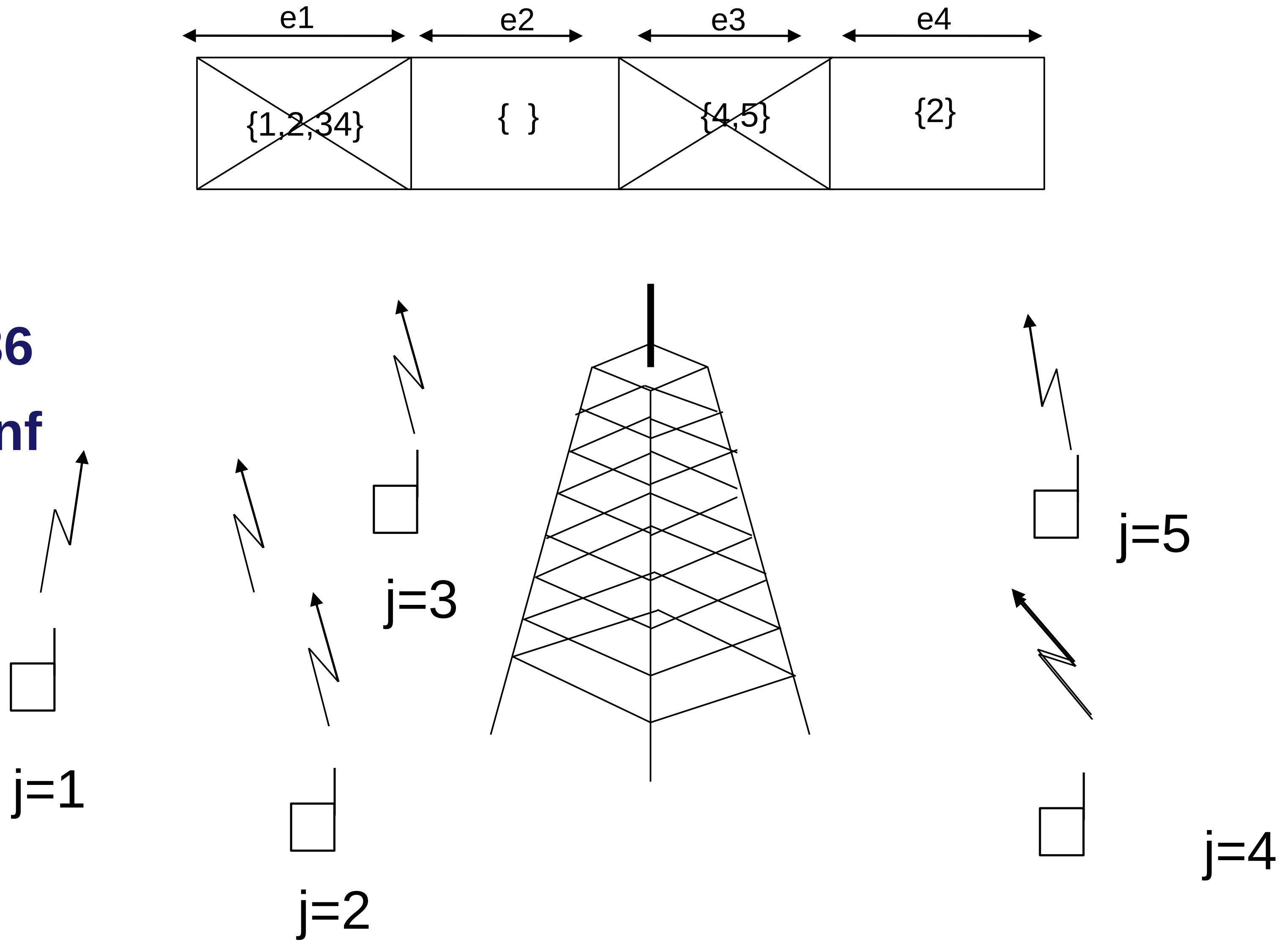
Erasure in random access

- Conventional random access discards all signals with collision
- Current commercial solutions still work under the ALOHA principle as proposed in 1970
- Erasure in random access leads to poor performance in high traffic load settings
- Future systems require better collision management

Erasure in random access

T=0.36

R=3:inf



Retransmission diversity

- Proposed in 2000. Called NDMA
- Nearly collision-free
- Collisions are not discarded
- Collision multiplicity estimation
- Retransmissions requested until MIMO channel is full rank
- Multiuser detection using linear decoding
- Less retransmissions than ALOHA
- Superior energetic efficiency

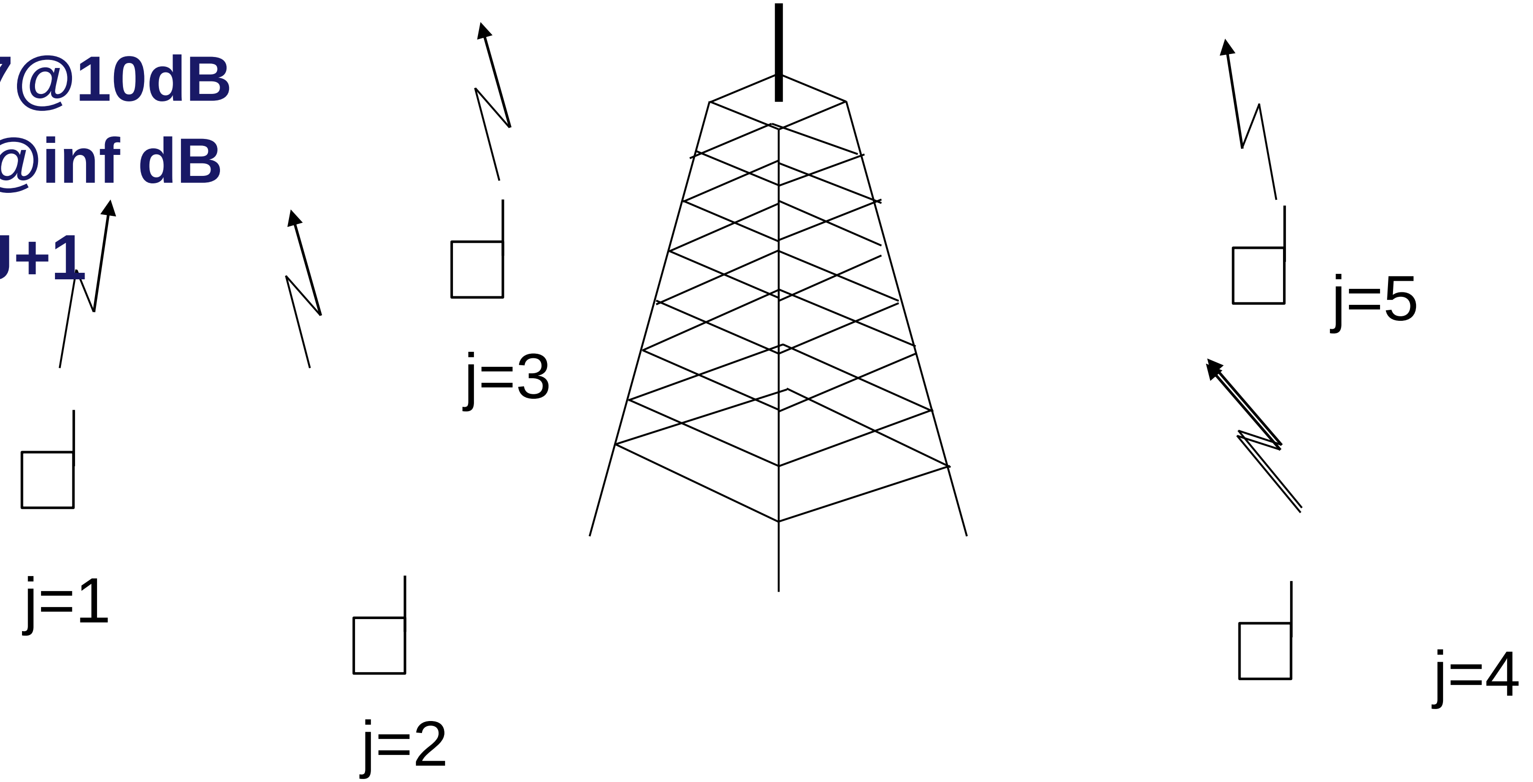
Retransmission diversity

e1				e2	e3	
{1,2,3,4}	{1,2,3,4}	{1,2,3,4}	{1,2,3,4}	{4,5}	{2}	{2}
{1,2,3,4}	{1,2,3,4}	{1,2,3,4}	{1,2,3,4}	{4}	{5,2}	{5,2}
1	1	1	0	0	1	0

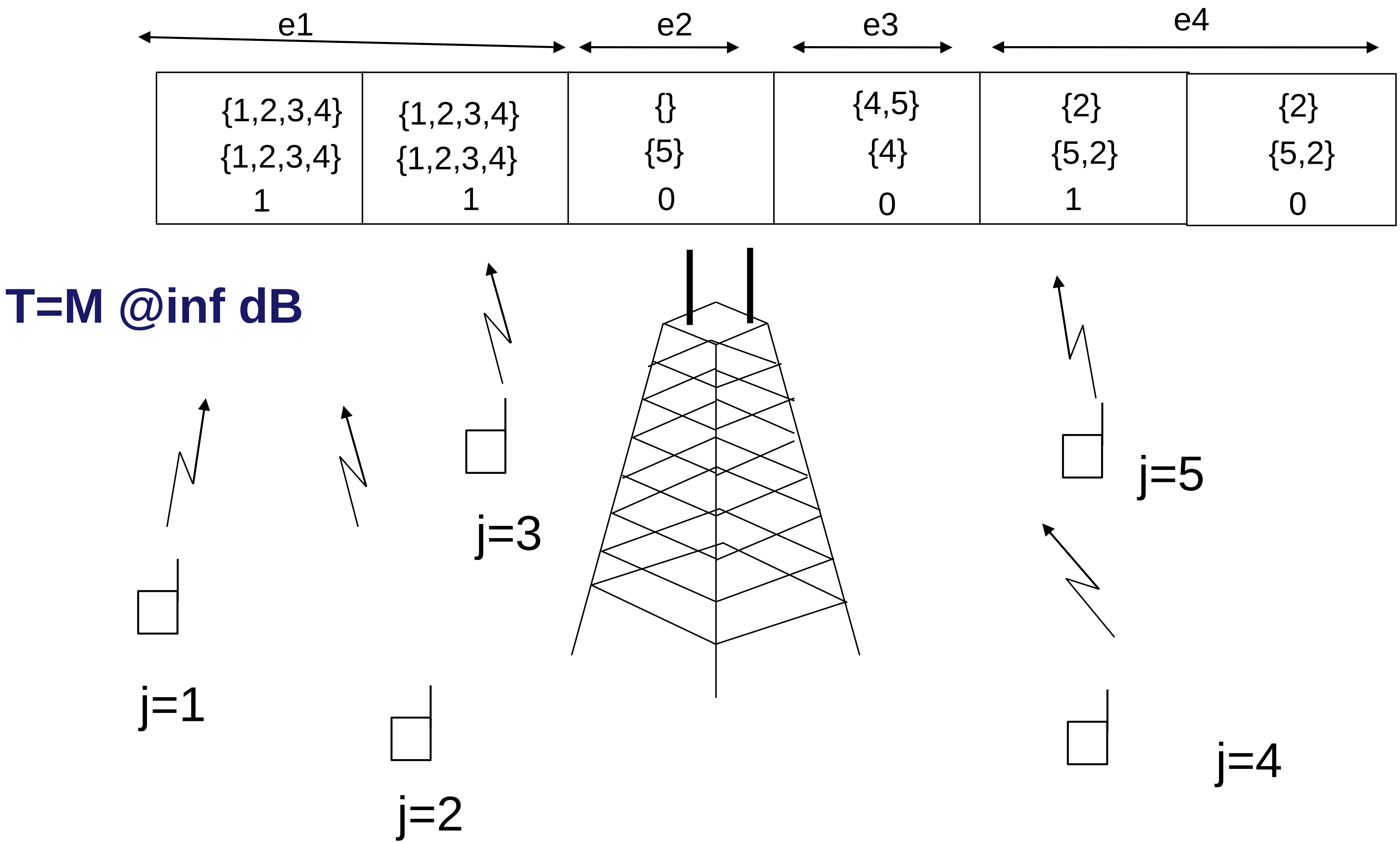
T=0.7@10dB

T=1 @inf dB

R=1:J+1



Retransmission diversity and multi-packet reception (2007)



Issues in NDMA

- Imperfect user detection
- Correlated retransmissions
- Orthogonal training sequences
- Collision multiplicity estimation
- Terminals retransmissions are costly in terms of energy consumption

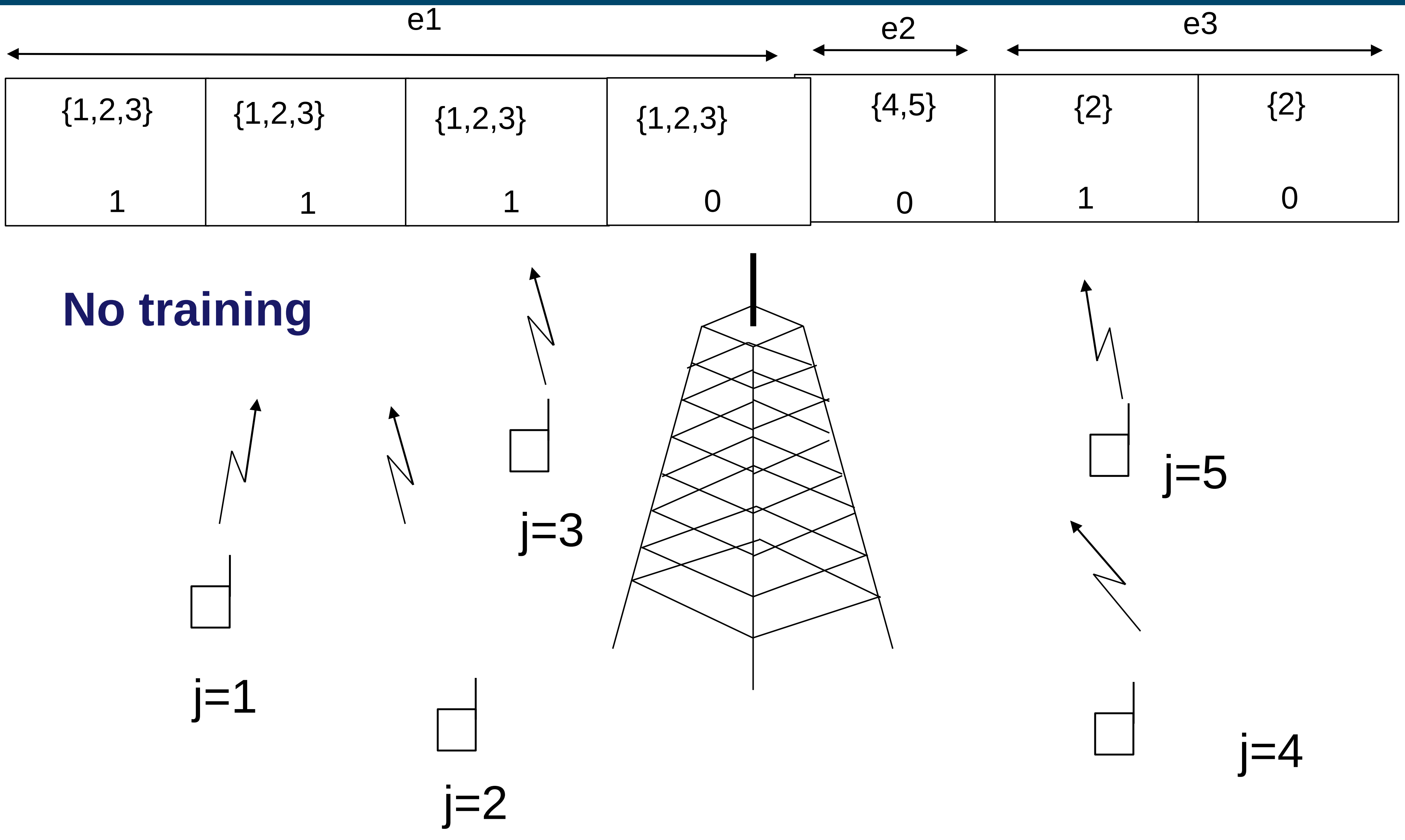
Blind NDMA(2004-2008)

- No training sequences
- Two solutions so far
  - Rotational invariance
  - Independent component analysis

- Blinds solutions are important for future dense networks
- They have experienced limited success due to practical limitations of blind algorithms in fading channels.

Blind NDMA

No training

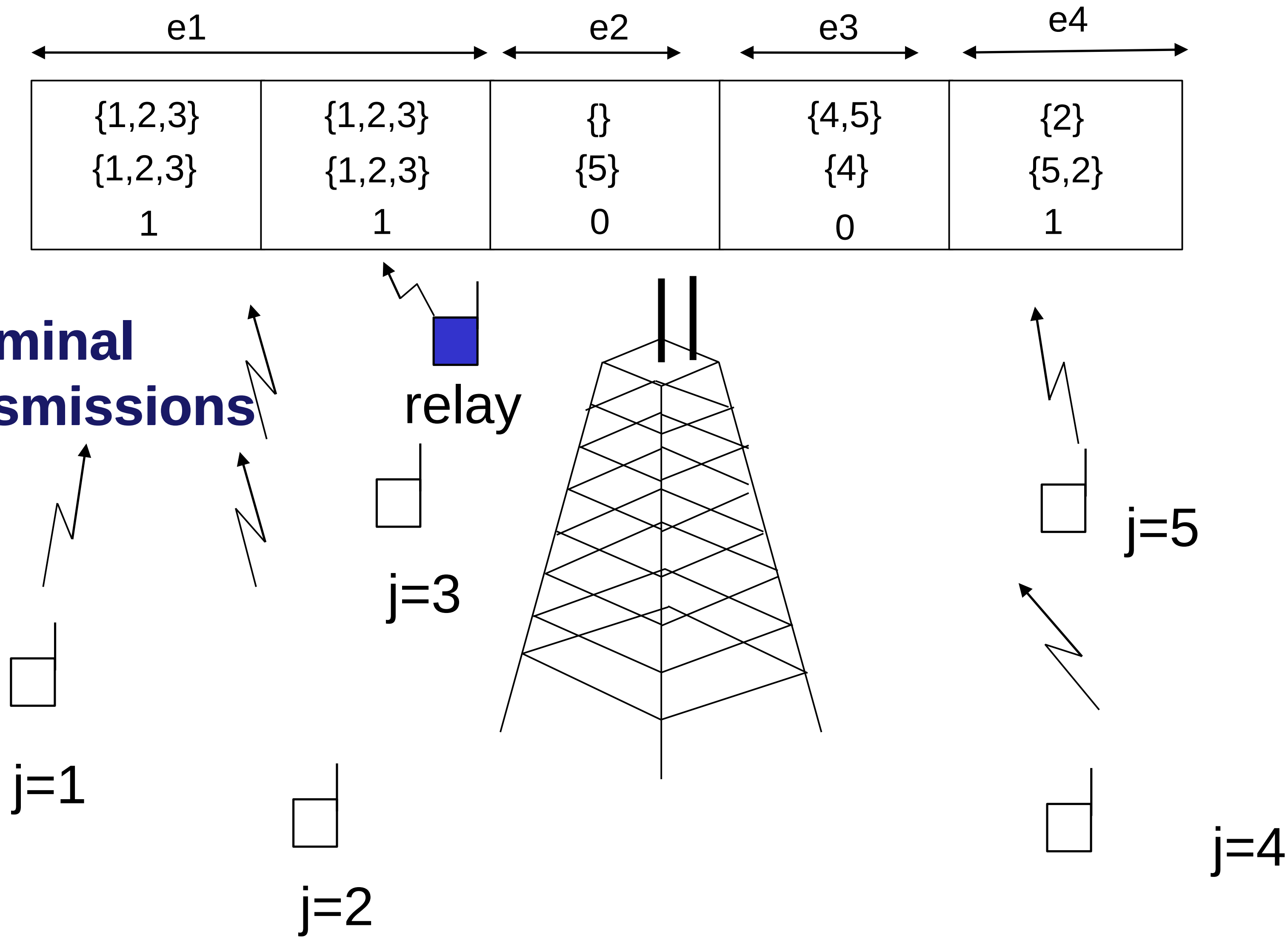


Cooperative NDMA(2007)

- Retransmissions not provided by terminals but by relays
- Reduction of power consumption
- Good against correlating fading channels in time and space

Cooperative NDMA

No terminal retransmissions



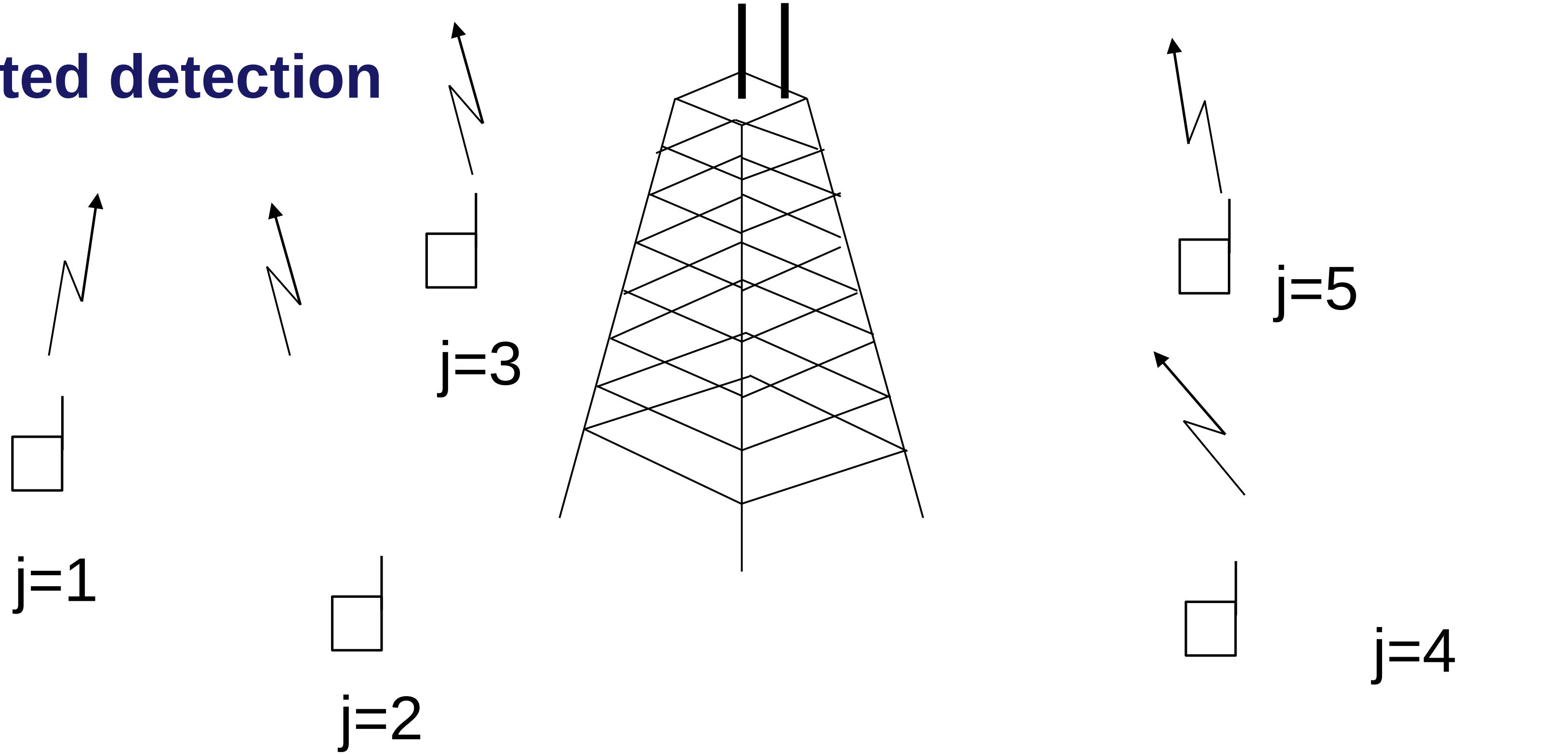
Sequential detection(in progress)

- Improves collision multiplicity estimation
- Higher throughput and lower delay
- Prone to time correlation

Sequential Detection

e1		e2	e3	e4	
{1,2,3}	{1,2,3}	{}	{4,5}	{2}	{2}
{1,2,3,4}	{1,2,3}	{5}	{4}	{5,2}	{2}
1	1	0	0	1	1

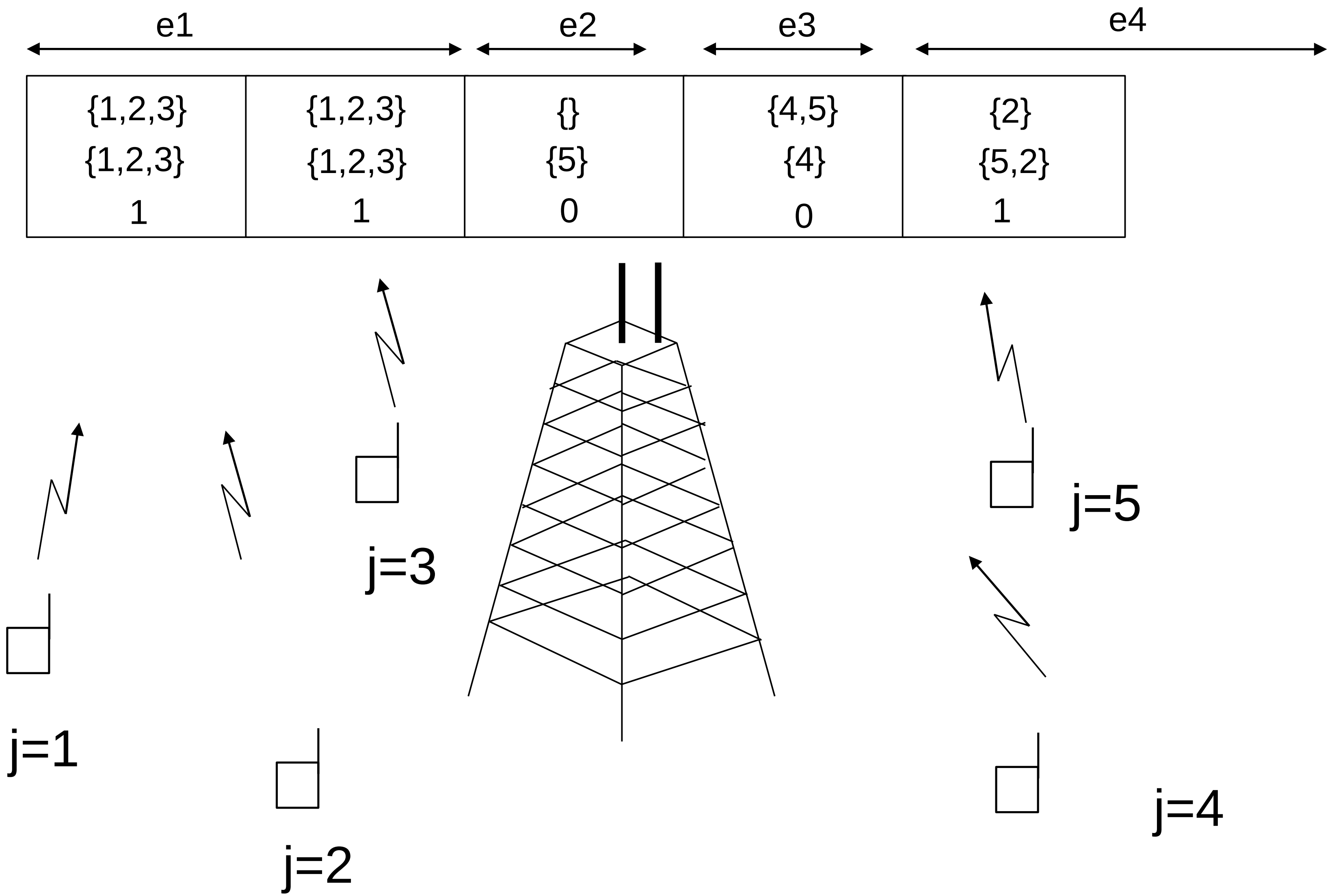
Updated detection



Correlated channels(in progress)

- Degrades diversity combining in MIMO systems
- Reduces independence and full-rank conditions
- Can be tacked via random phase modulation

Correlated channels

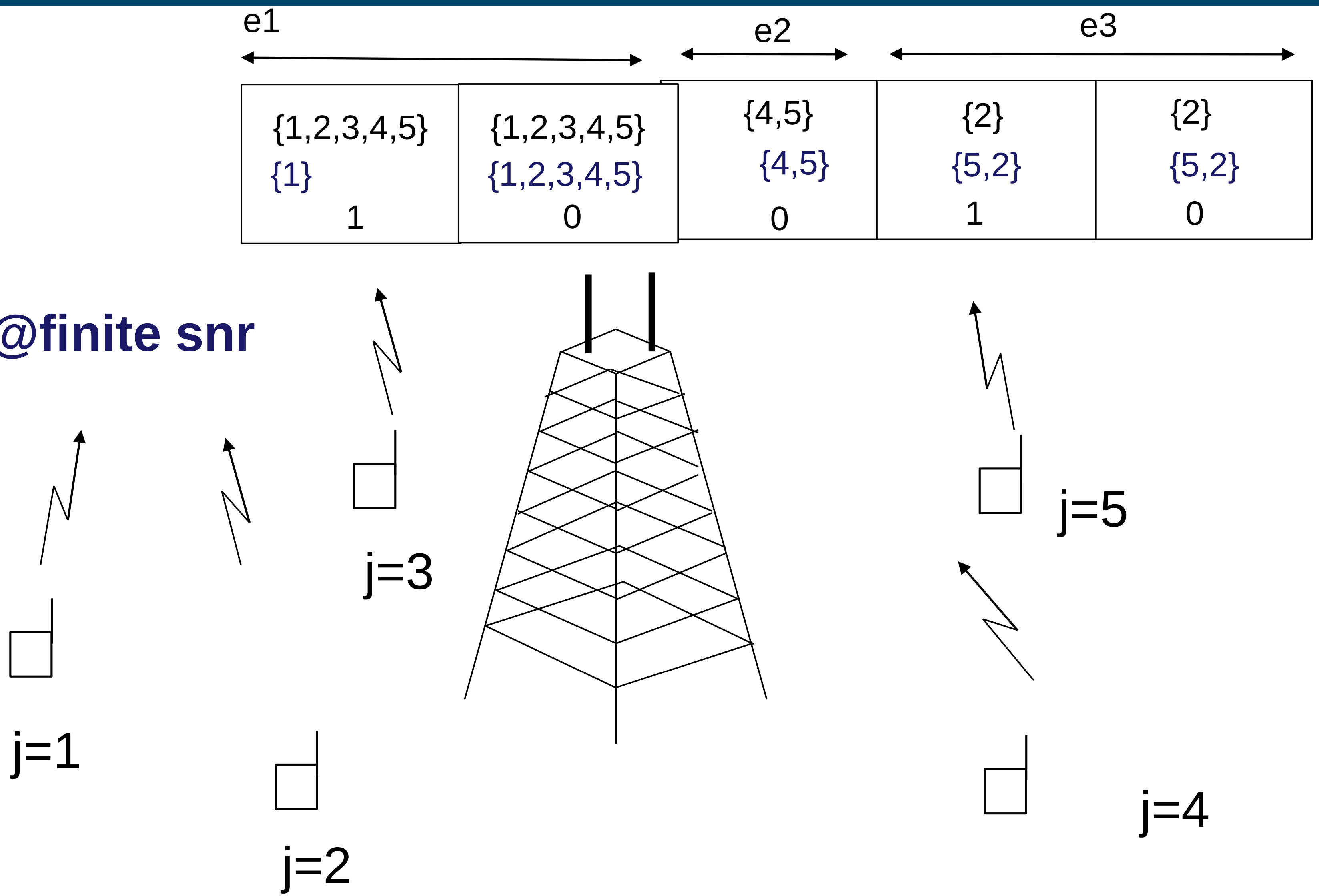


Successive interference cancellation in NDMA-MPR (in progress)

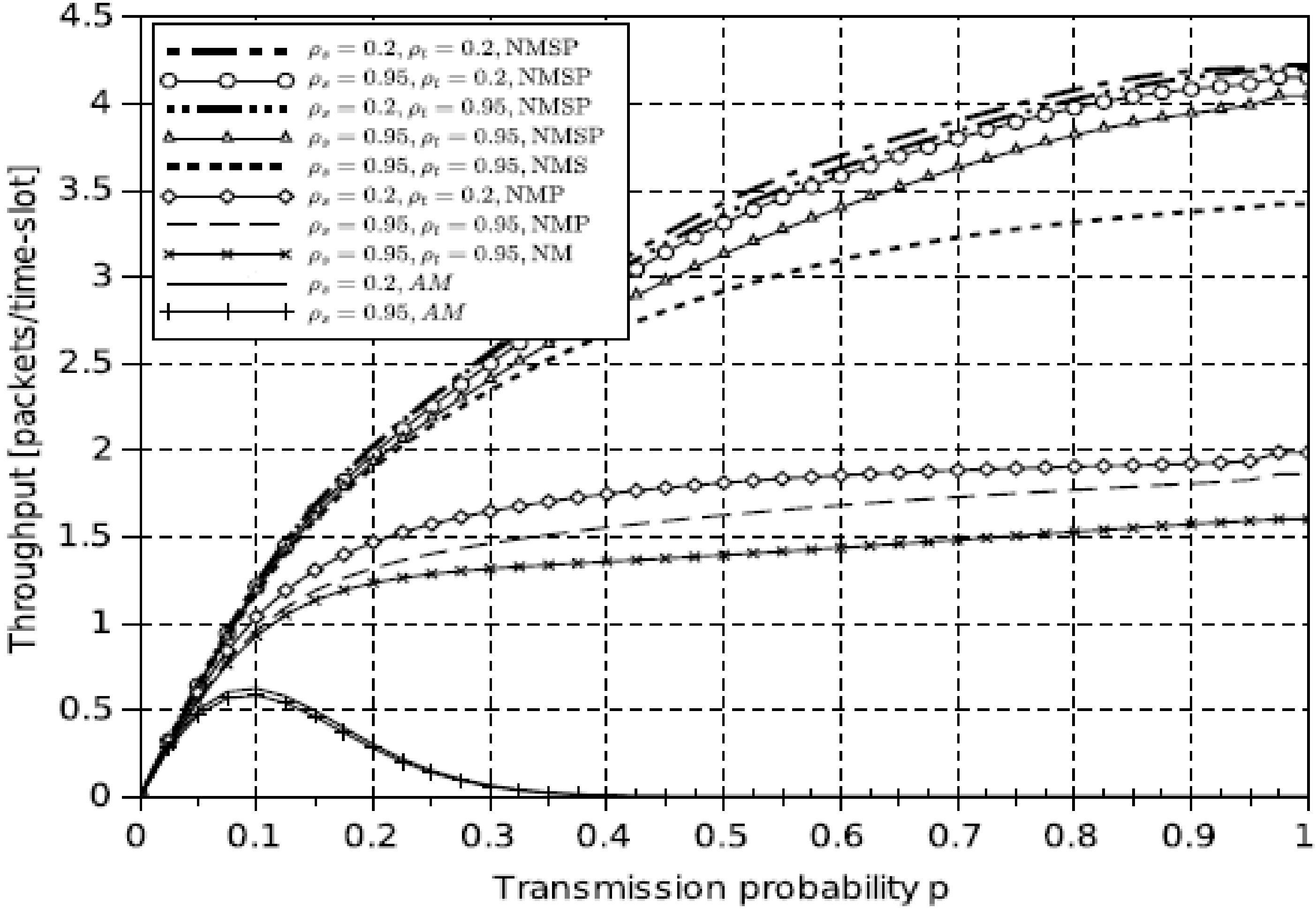
- BS attempts the decoding immediately after reception of each retransmission even if MIMO channel is rank deficient
- Some signals might be correctly decoded.
- These signals are used to subtract interference to the rest of users
- Collisions are resolved in a reduced number of time slots
- Historical maximum for achieved throughput T>M even for finite values of SNR

Successive interference cancellation in NDMA-MPR

T>M @finite snr



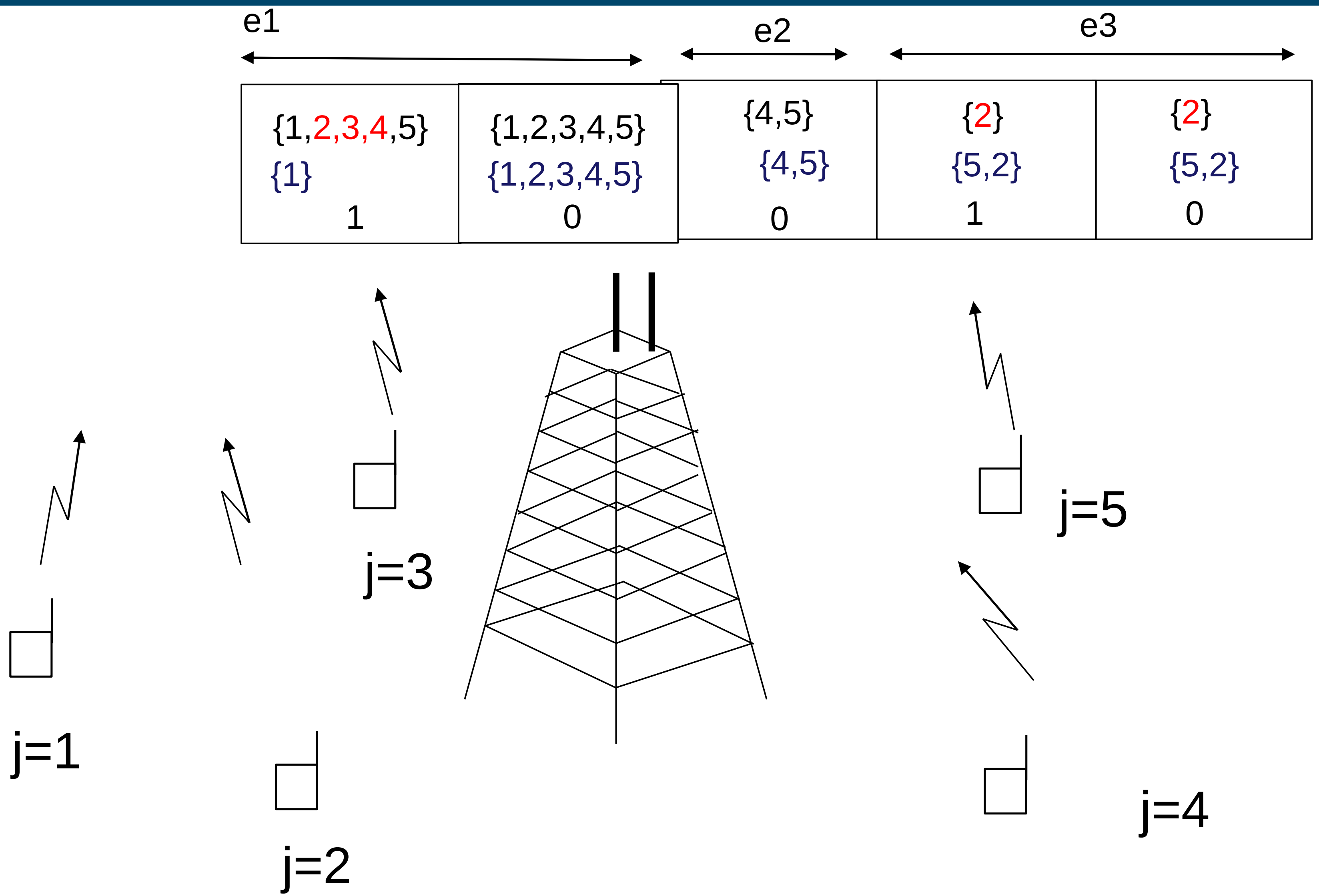
Successive interference cancellation in NDMA-MPR



Semi-blind NDMA+MPR+SIC

- Terminals share training sequences
- Users with same sequence use Semi-blind processing
- Users with different sequence use training-based processing
- Potential huge gains in throughput and training bandwidth

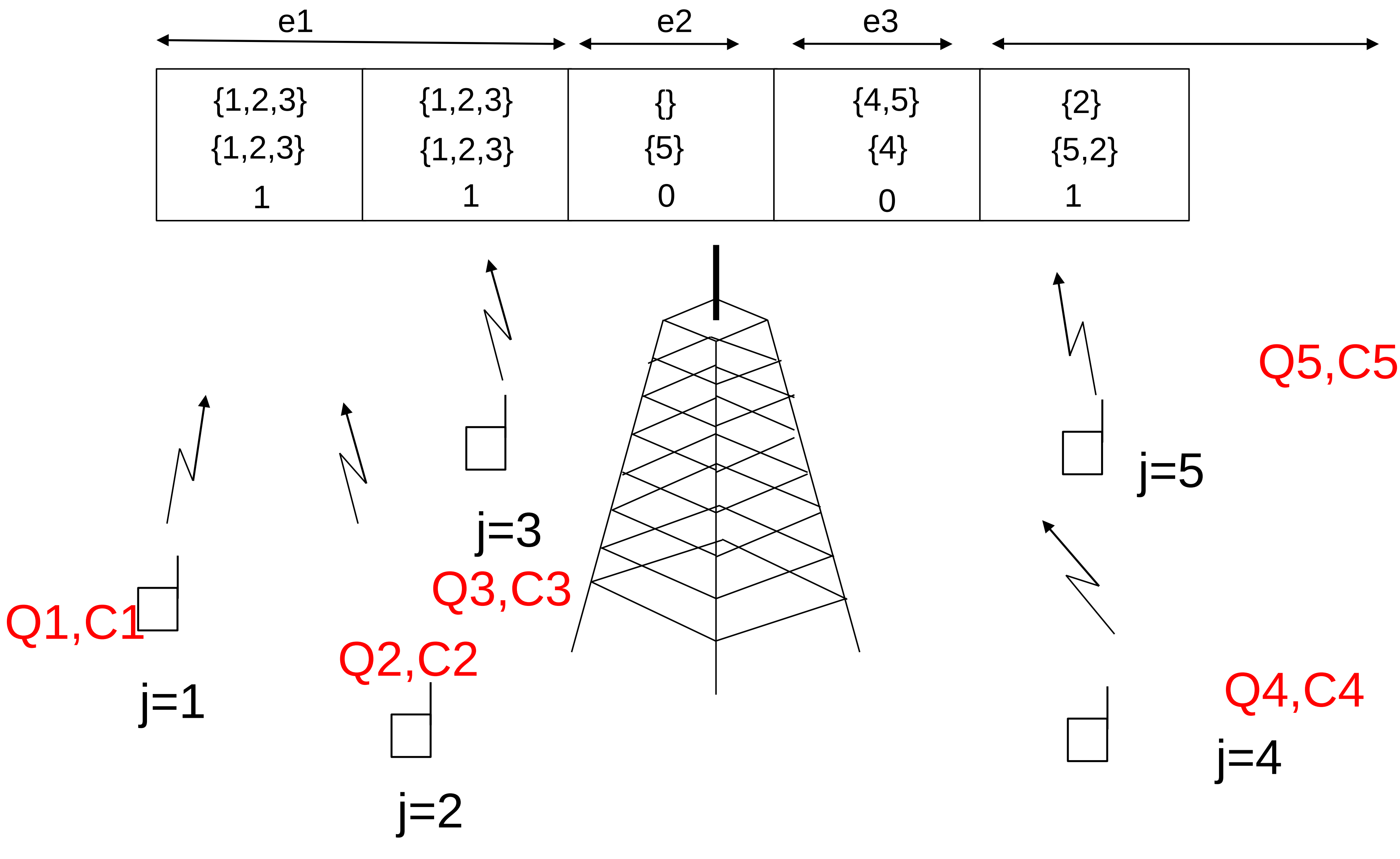
Semi-blind NDMA+MPR+SIC



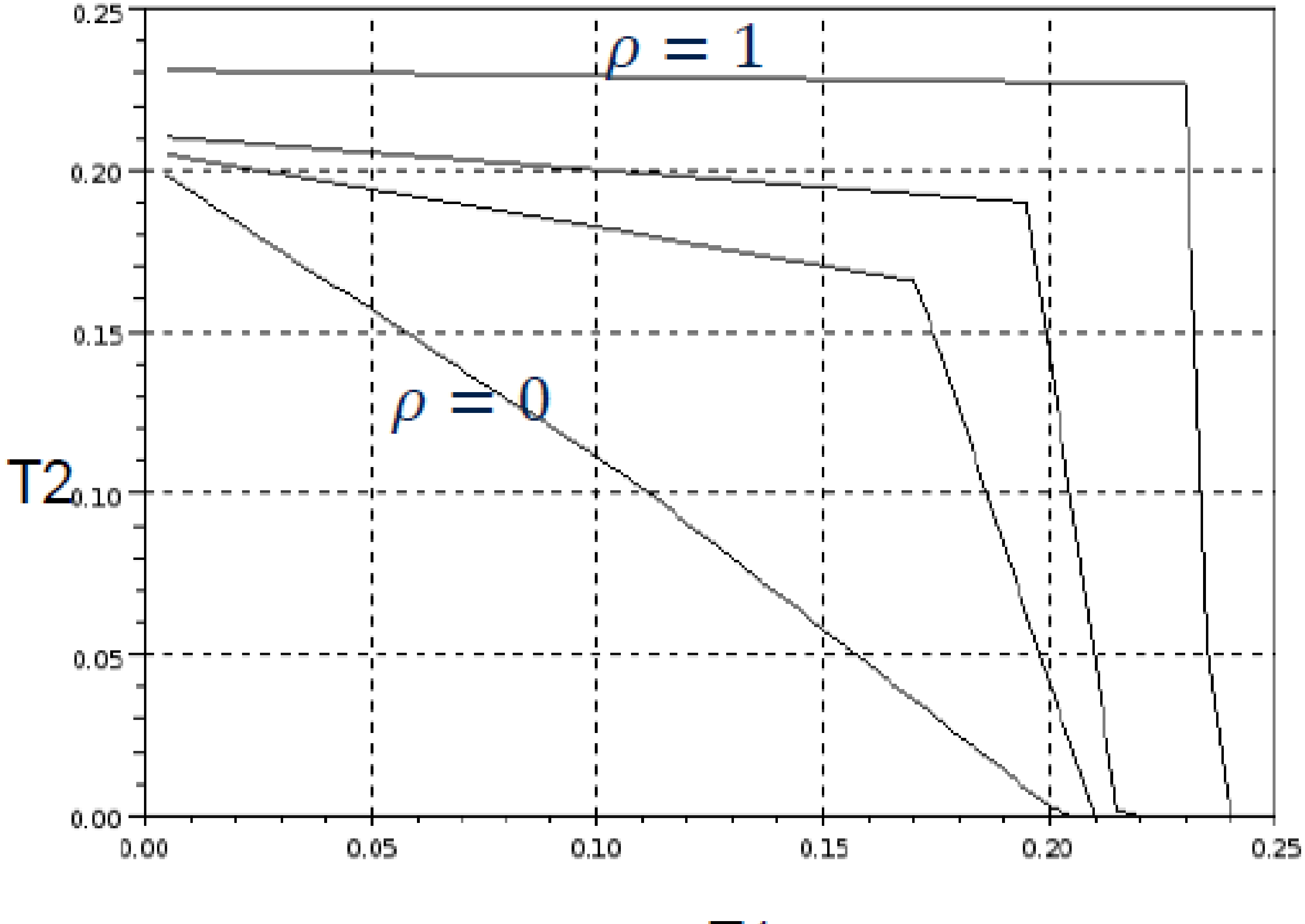
Imperfect CSI/QSI + RD/MPR/SIC

- Terminals or groups of terminals have access to different levels of quality of channel and queuing state information of different parts of the network.
- This will be a typical scenario in cognitive, self-organized, software-defined and cooperative networks.
- Each terminal or group of terminals decide when to transmit (scheduling).
- Terminals allocate power, modulation and coding, the number of retransmissions according to the available CSI and QSI.
- Remaining errors are resolved by means of RD-MPR-SIC.

Imperfect CSI/QSI + RD/MPR/SIC



Imperfect CSI/QSI + RD/MPR/SIC



Interference alignment + NDMA

- Terminals have now multiple antennas to transmit.
- Based on the available CSI/QSI terminals calculate the optimum subspace to transmit and to avoid interference (interference alignment) in addition to power, MCS, scheduling decisions, and retransmissions.

Interference alignment + NDMA