Rethinking reliability for challenged networks

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Outline

- Context
  - Network Robot Systems
  - Challenged Networks
- Proposal
- Results
- Current and futures works

Telerobotics and Network Control Systems

« The defining feature of an NCS is that control and feedback are exchanged among the systems components in the form of information package through a network », **NSC Basics**

Issues:

- **System performance, i.e fast response, low data loss ratio…**
- System reliability
- System security
- System flexibility i.e (plug and play…)

L. Li and F. Wang, June 2008, Control and Communication Synthesis in Networked Control Systems, *International Journal of Intelligent Control and Systems, Vol. 13,* 81-88

Network Robots Systems

- Mobility ?
- Variable nodes density ?
- Dynamic environement ?
- Interference ?
- High loss rate ?
- Intermitent connectivity ?
- Multiple network interfaces ?
- …

A. Sanfeliu , N. Hagita and A.Saffioty, July 2008, Network Robot Systems, *Robotics and Autonomous Systems, Vol. 13,* 793-797

Challenged Networks…

“”Challenged networks include those found in mobile and in-motion networking, dynamic wireless networks, heterogeneous and mobile sensor networks, interplanetary networking, and providing rural connectivity. Such networks are not well served by standard TCP/IP solutions, due to the prevalence of disconnection, disruption, intermittency, large delays, or other factors.”” **Kevin Fall**

- Intermittent connectivity
  - Mobility, radio propagation, battery issues
- Long propagation delays
  - Under water systems, satellite links, data mules
- Asymmetric data rates
  - Almost or completely unidirectional
- High error rates
  - Lossy environment

Challenged Networks…

Regular end-to-end communication protocols may fail

(e.g., TCP, OSPF)

Need to restate the communication paradigm

- Routing layer
  - Store and forward paradigm
    - Routing metrics based on the underlying mobility:
      - *Prophet, Maxprop, Mobyspace, DA-SW, SW, Sim-Bet, BubbleRap, CARS, Rapid (…) …*
  - MANET routing algorithm
      - DSDV, OLSR, AODV, ZRP, CBRP, TORA, DSR, CGSR, HSR (…) …

Challenged Networks...

- Transport Layer:
  - Many TCPs variant
    - None of them is designed for the Challenged Networks requirements
  - DTN Transport layer
    - LTP-T, Saratoga, UNI-DTN..

- « Transport layer issues remains to be adressed in DTMN »
  - K. Harras and K. Almeroth, May 2006, Transport Layer Issues in Delay Tolerant Network, *IFIP 06*

Full reliability is still dependant of an Acknoledgement Path, retransmission and RTT !

Questions ?

- How can we enable full reliability without an acknowledgement path?
- Can we design a tolerant to acknowledgement losses reliable mechanism?
- Can we design a generic mechanism (bulk data transfer + realtime ?)
- **Definition**: We define as tolerant to acknowledgement losses a mechanism which **does not need timely updated information from the receiver** to determine which **packets must be resent** without impacting on the data availability at the receiver side.

J. Lacan and E. Lochin, Rethinking reliability for long delay networks Oct 2008, In Proc. Of IWSSC

Our proposal

- Building such mechanism: tolerant to ACK-losses based on a new erasure coding scheme
  - Idea: combining network coding + transport protocol
- In its most general form full-reliability can be achieved
- Presents really good properties for realtime apps (VoIP, video-conferencing)
  - Indeed : not self-clocked mechanism
  - In particular : low delay in terms of data recovery

The big picture

- Most of erasure codes used over packet erasure channels are block codes
  - A set of repair packets is built from a set of source data packets
  - If few losses => redundancy are useless
  - Alternative Hybrid FEC-ARQ
    - Use receiver feedback to send or adjust redundancy
- Burst erasure codes (Martinian & Sundberg 2004) use a sliding window
  - Designed for « real-time » purpose
- **Our proposal => mix of these contributions**
  - Build redundancy with an **elastic window** updated when possible by **non-mandatory rcv feedback**

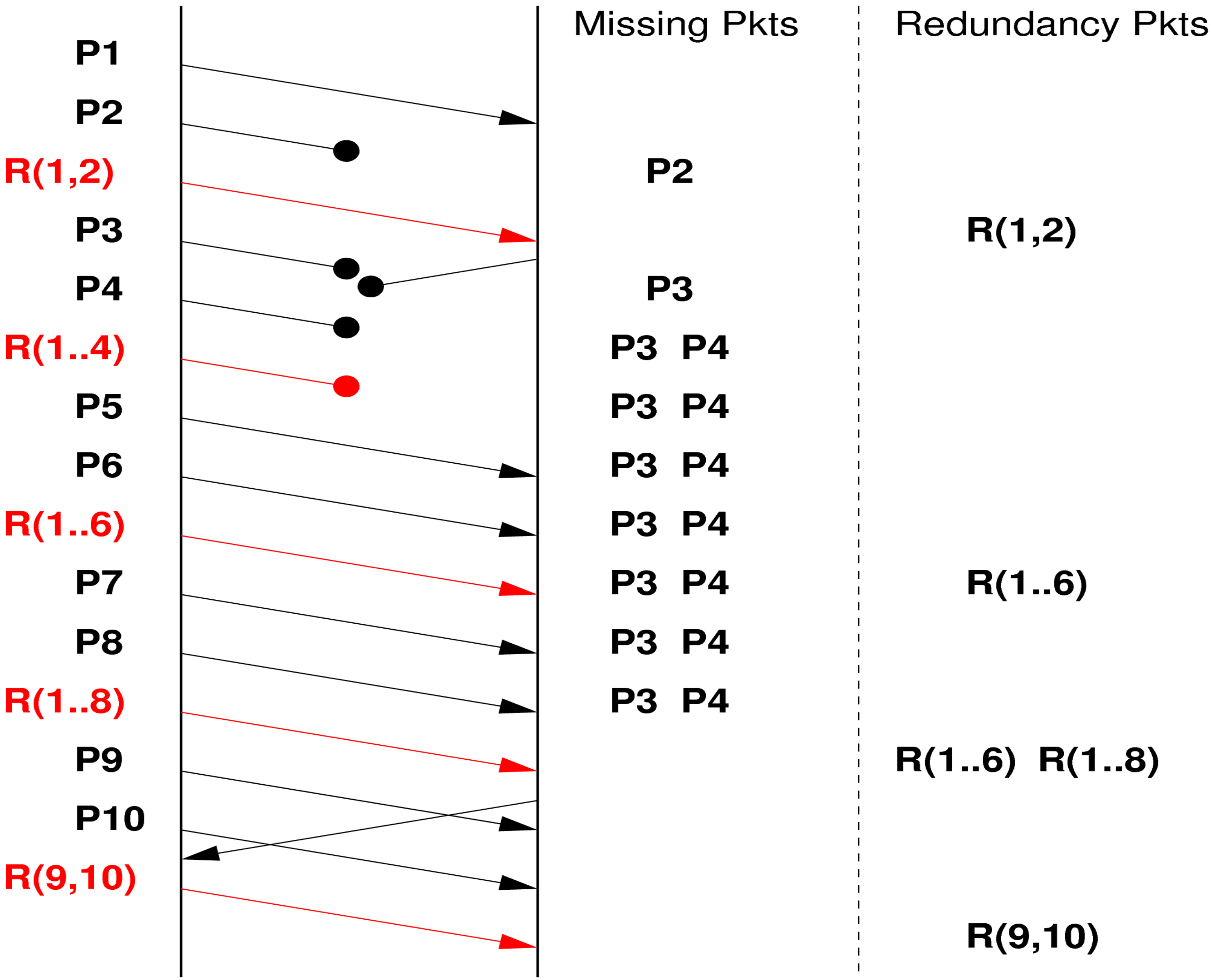
Basic rules

- Redundancy packets are built from data packets ranging from 1 to n unless one feedback received
  - P1 – P2 – R(1,2) – P3 – P4 – R(1,4)
  - To generate R: sender computes a linear combination over a binary or non binary finite field

- When nb redundancy packets == nb lost ones
  - 4 losses mean a 4x4 matrix to invert in order to rebuild all packets

- Downlink is not mandatory but useful to decrease computation complexity
  - Can also be used to confirm data arrival to the sender
  - Use of « seen » packets concept
    - cf. IEEE ISIT 08 « ARQ for Network Coding » Jay Kumar Sundararajan, Devavrat Shah, Muriel Médard

Main principle



« Sack when seen » strategy

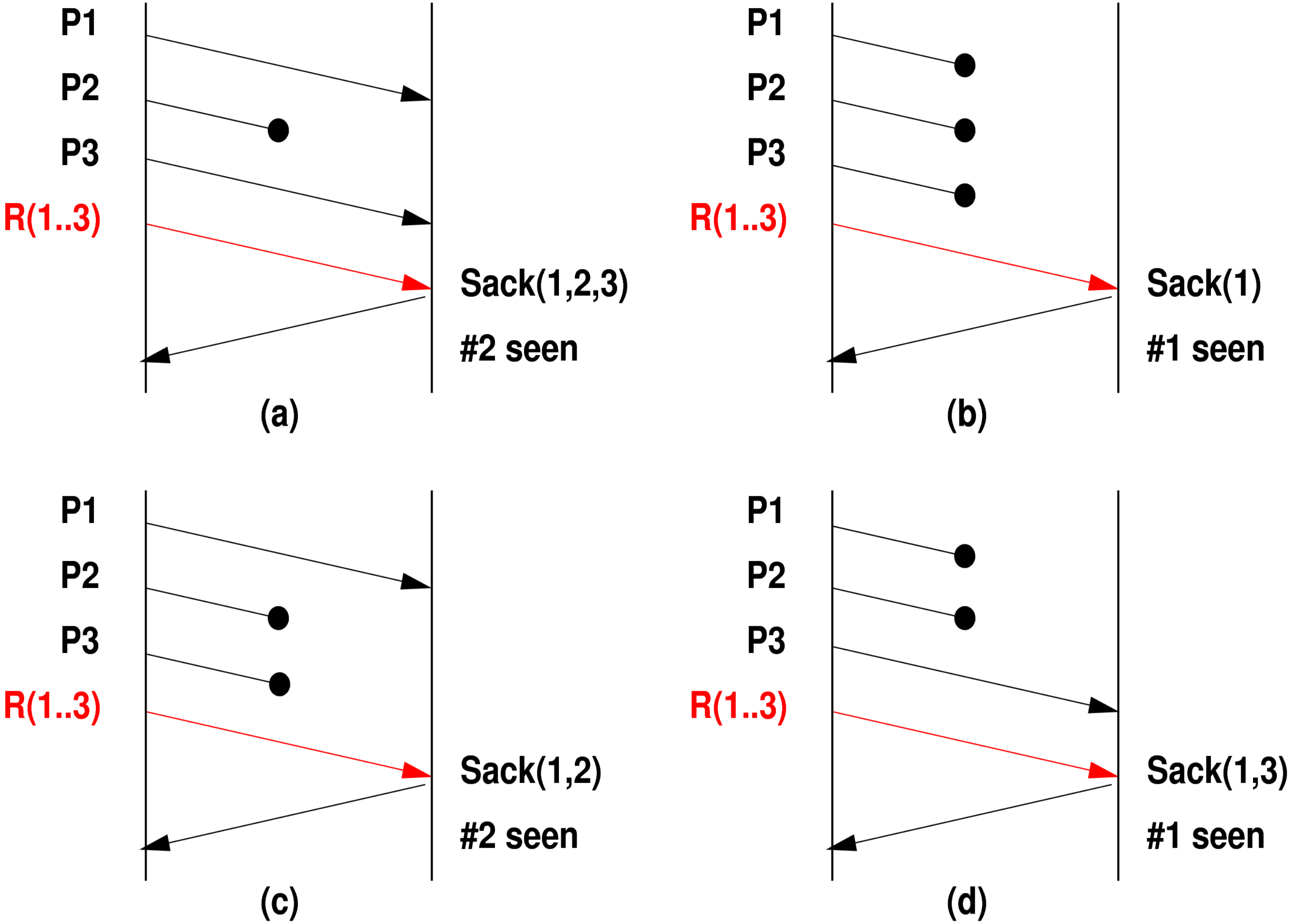
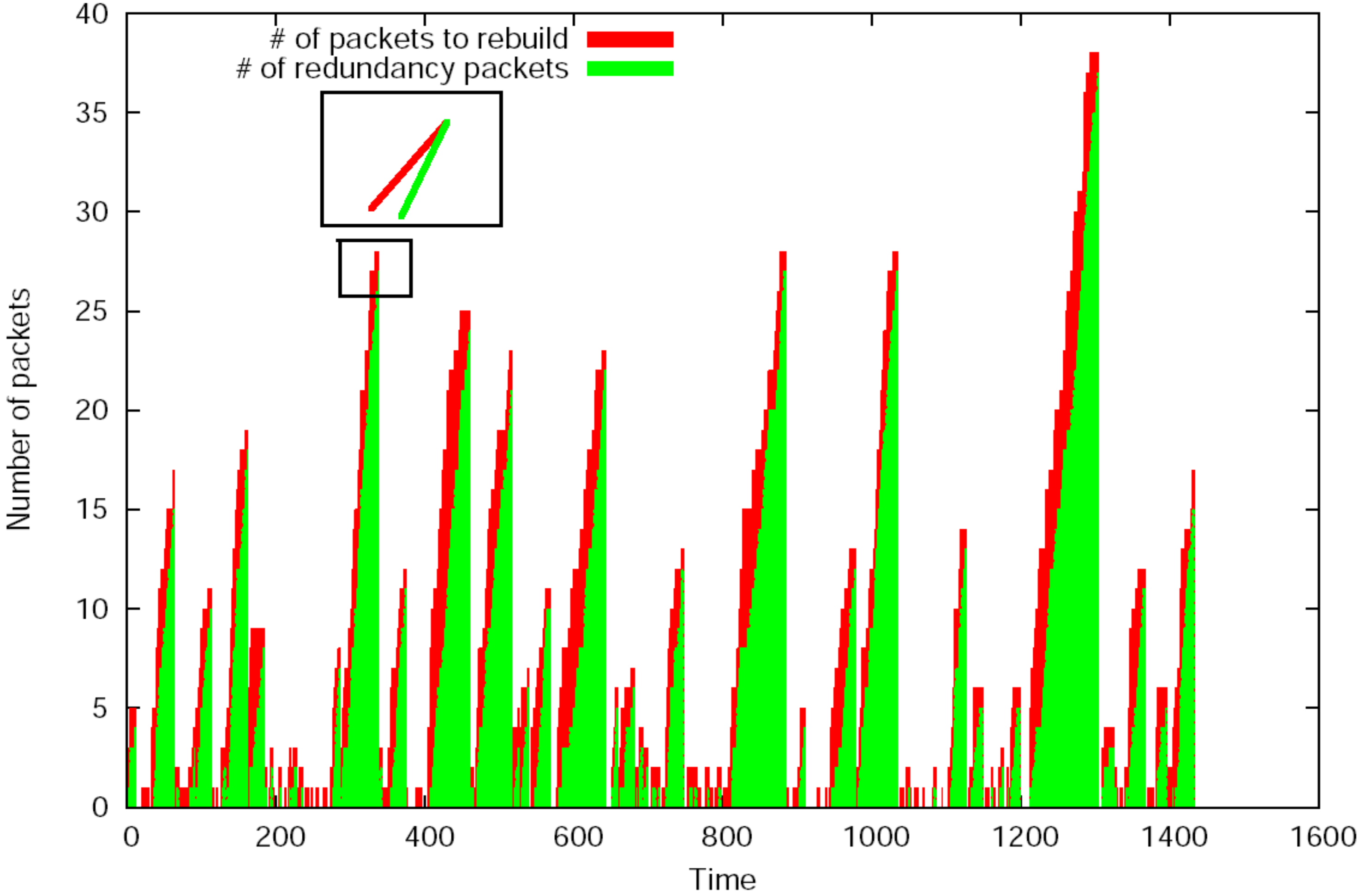


Illustration results (plr=20%)

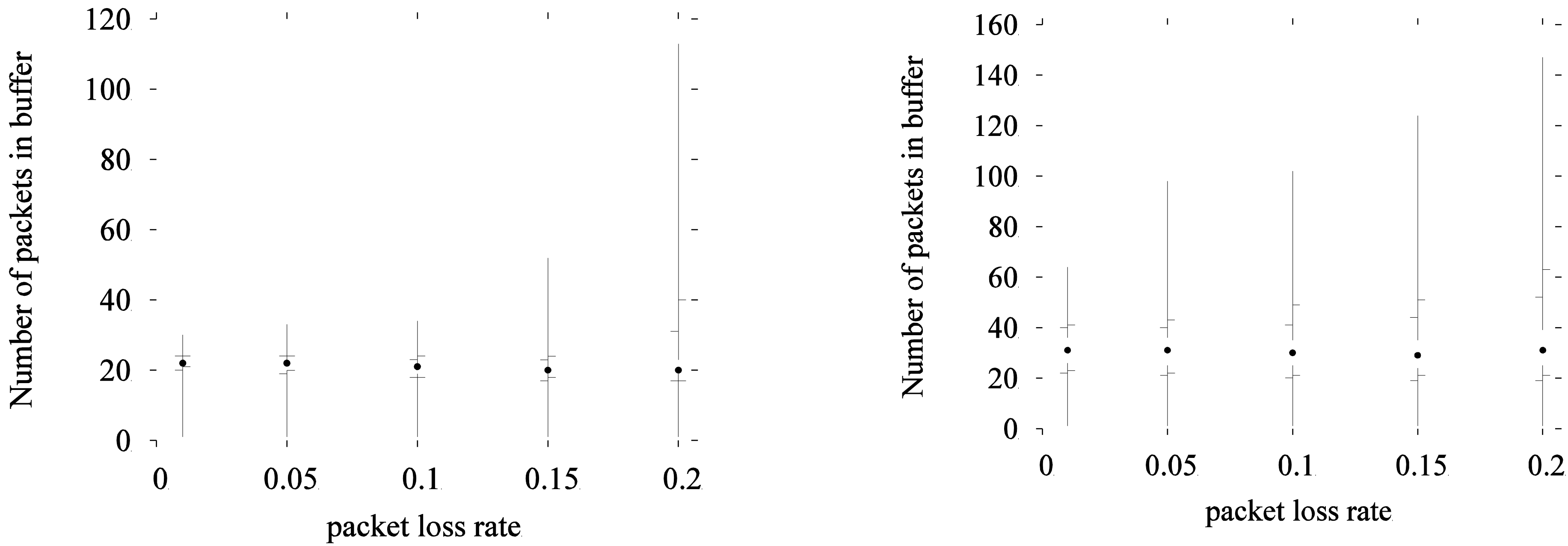


Implementation Issues

- The recurrence time
- The mean distribution of the inverted matrices size
- The buffer sizing at the receiver side
  - Evolves linearly as a function of packet loss rate

Both CPU and storage ressources remains within realistic bounds

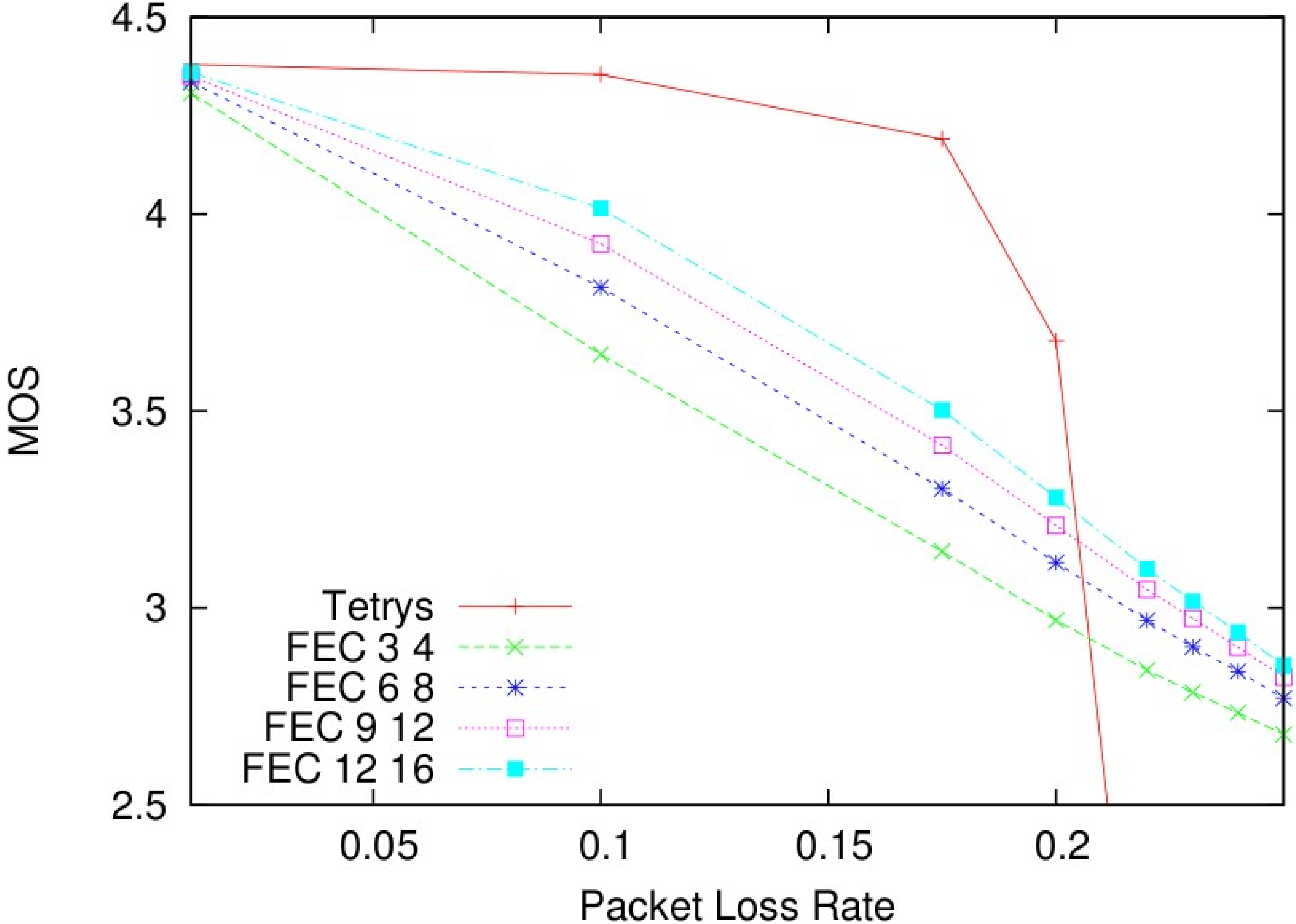
Implementation Issues: Exemple



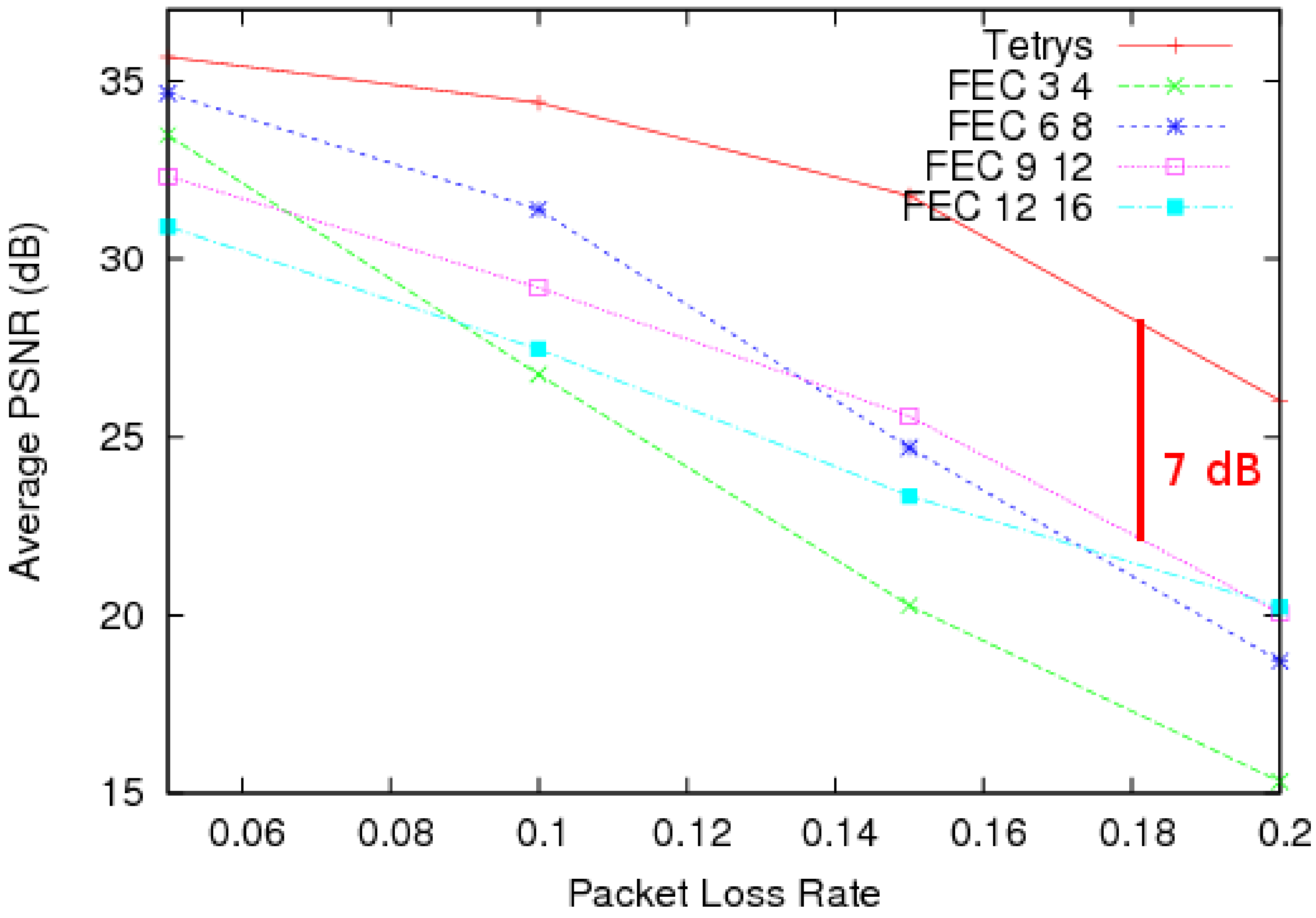
Buffer size as a function of Packet loss rate for one Ack per received packet (left), one per RTT (right)

Further results in ISAE Tech-Report http://arxiv.org/abs/0904.4202

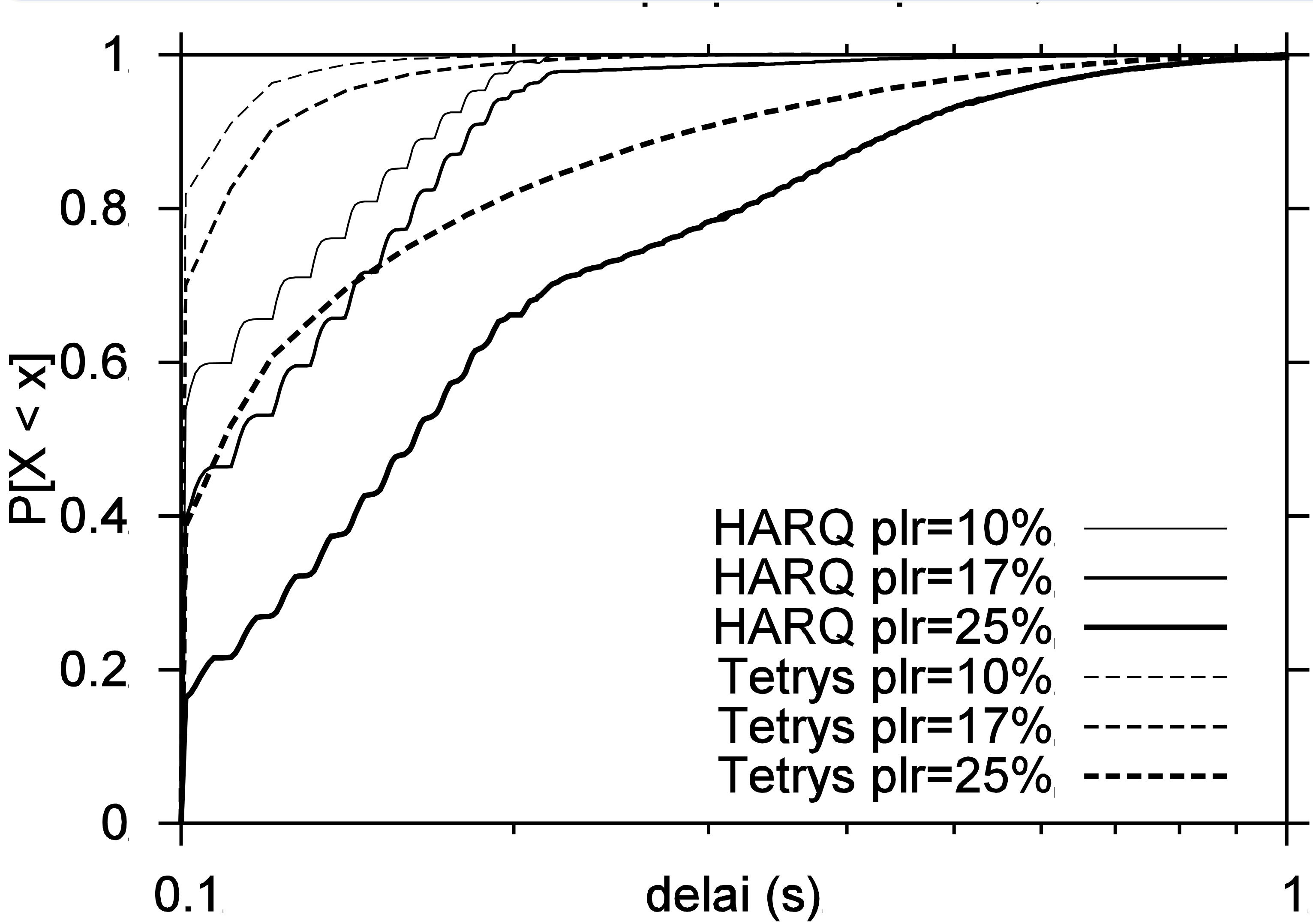
VOIP results



Video conferencing results:



In order delivery delay
(for full-reliability)



Current Work: TCP, UDP

- Add a full-reliability layer below TCP or UDP

WHY ?

- Enable TCP real-time behaviour
- Reduce transfert duration

HOW ?

- Transparent: No modifications needed on TCP sources codes
- Allow a wide and fast adoption and deployement

Current work: Analysis

- « Elastic encoding » always outperform HARQ, ARQ schemes
  - It can be proved… To be done
- Estimate Protocol parameters to remain below an expected delay
  - In function of sending rate and loss rate

Current Work: DTMN
(Delay Tolerant Mobile Network)

- Full-Reliability Transport Layer for DTMNs
  - Implementation inside Saratoga , LTP-T or UNI-DTN ?

WHY ?

  - Current Routing protocols/networks have a low bundle delivery ratio
  - Acknoledgement path often not exists
  - RTT can be very large in those networks !

Current and future works

- Extend previous measurements
- Design the way to implement it in a congestion controlled protocol (a rate-based ?)
- Reliable multicast

Conclusion

The loss recovery delay / RTT depency is now broken

A wide panel of applications over:

- Internet
- Networked Robots..
- DTNs / DTMNs

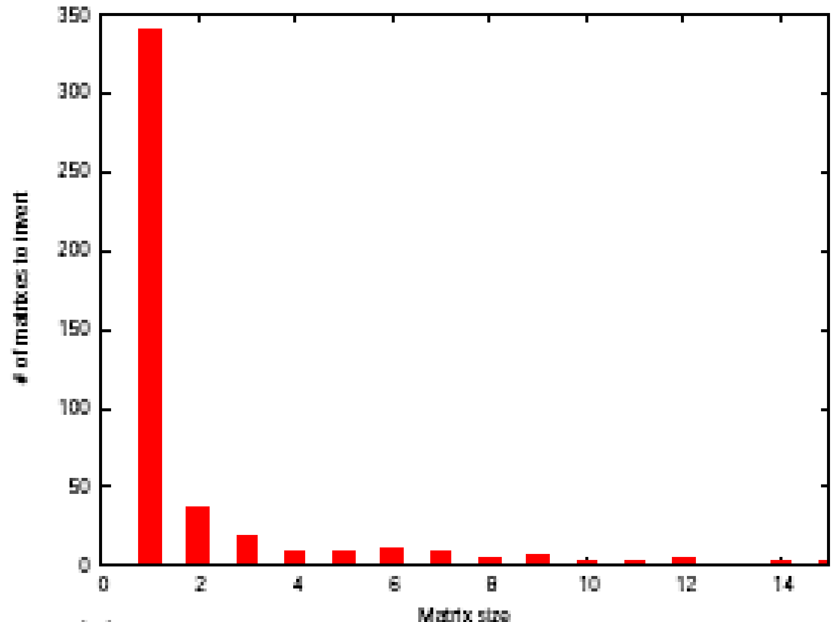
A prototype for Real-time (Video conf, VOIP..), Robotics, bulk transfer is almost ready

Questions ?

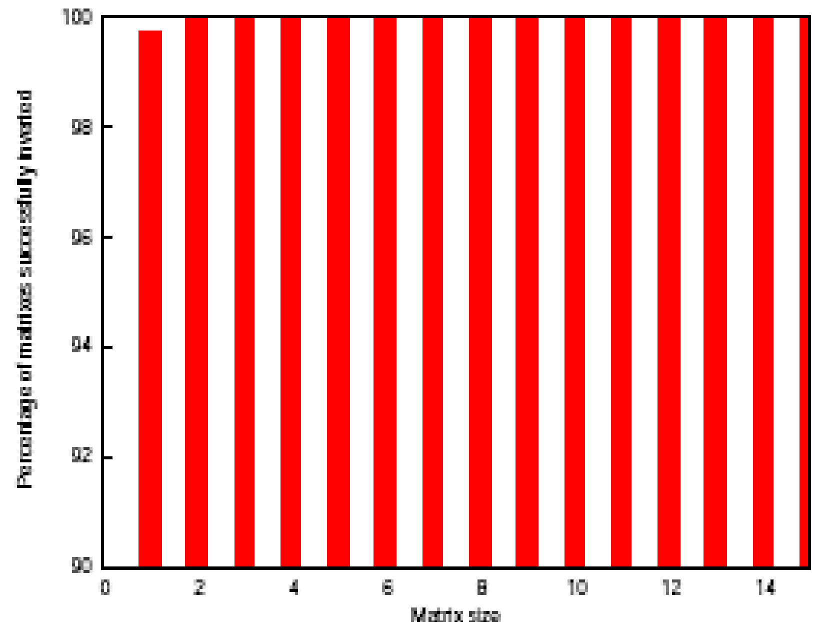
- Thank you !

Backup Slides

Matrix inversion statistics

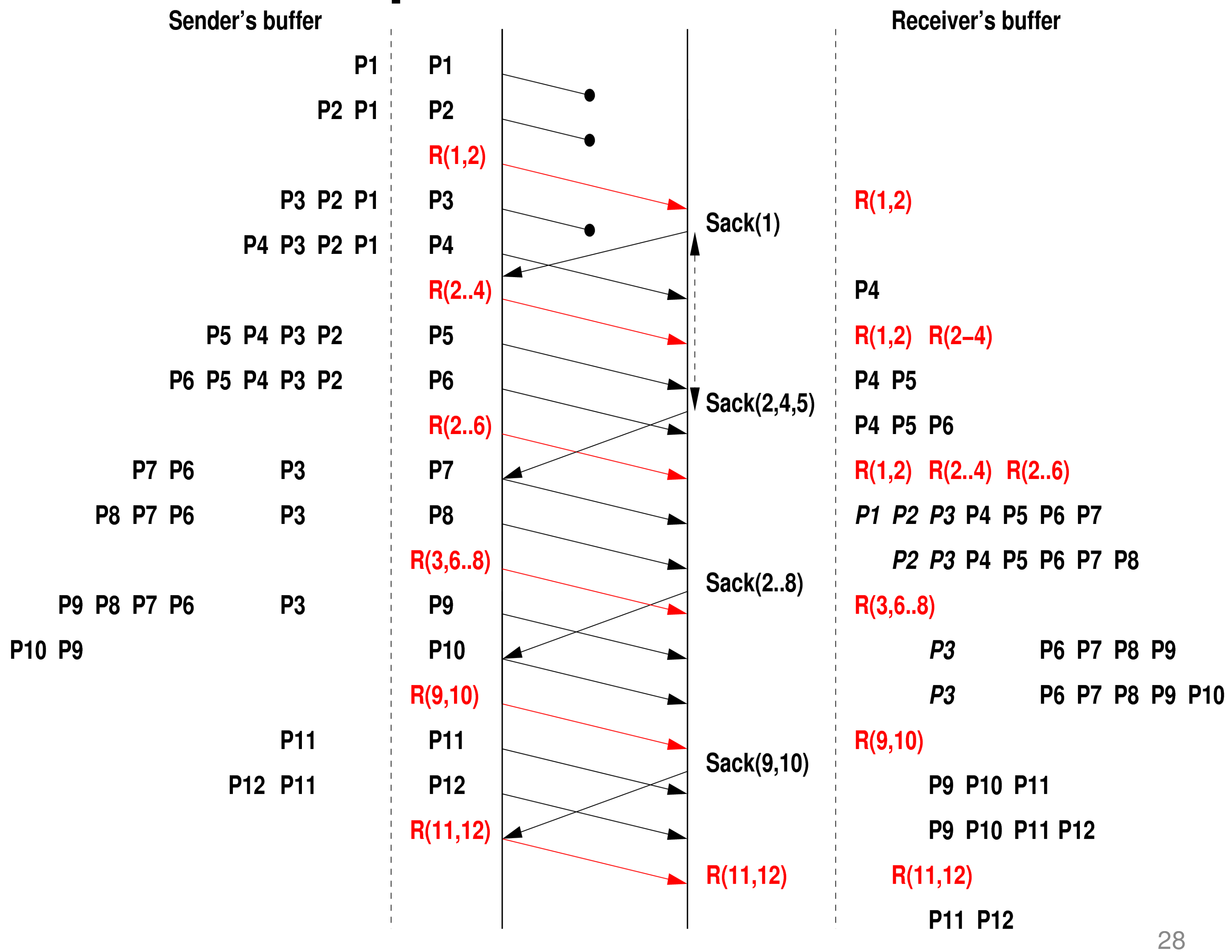


(a) Number of matrices to invert



(b) Percentage of matrices successfully inverted

Complete Overview



Matrix inversion

- High probability of being invertible
  - If finite field choosen sufficiently large

P1	P2						
P1	P2	P3	P4				
P1	P2	P3	P4	P5	P6		
P1	P2	P3	P4	P5	P6	P7	P8

$$(R'^{6}_{1}, R'^{8}_{1})^T = \begin{pmatrix} \alpha_3^{(1,6)} & \alpha_4^{(1,6)} \\ \alpha_1^{(1,8)} & \alpha_4^{(1,8)} \end{pmatrix} (P_3, P_4)$$