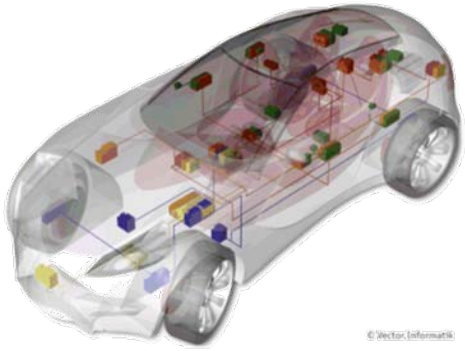
Protocol Verification and State Space Methods

Wojciech Penczek
Institute of Computer Science
Polish Academy of Sciences, Warsaw, Poland
Email: penczek@ipipan.waw.pl **/ Web:** www.ipipan.waw.pl/~penczek/

Lars M. Kristensen
Department of Computer Engineering
Bergen University College, Bergen, Norway
Email: lmkr@hib.no **/ Web:** www.hib.no/ansatte/lmkr

Communication Protocols

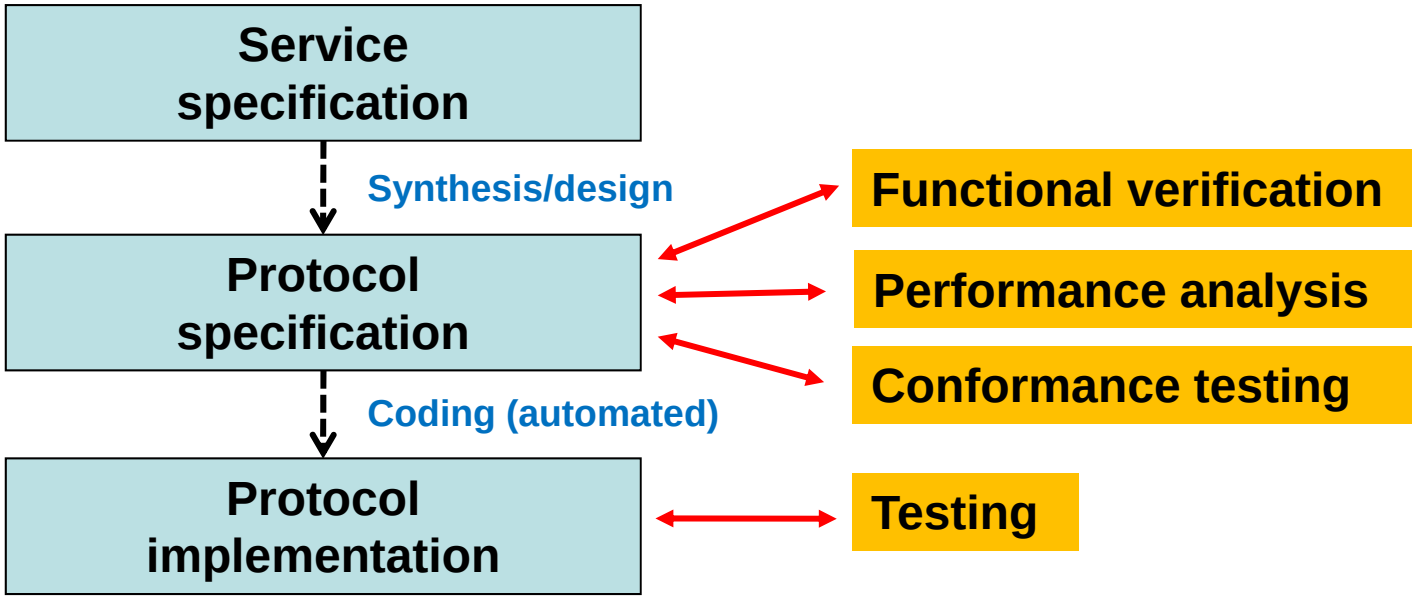
- **Communication protocols play an increasingly important role in our everyday life:**



- **Building blocks governing the interaction between entities in data communication (Holzmann'91):**
  - Service to be provided by the protocol.
  - Assumptions about the environment in which the protocol is executed.
  - Vocabulary of messages used to implement the protocol.
  - Encoding (format) of each message in the vocabulary.
  - Procedure rules guarding the processing of messages.

Protocol Engineering

- **The development of protocols involves a number of activities** [Liu'89]:



  - **It is important that protocols are working correctly from the very beginning.**
  - **A key application domain for Petri nets, concurrency theory, and model checking technology.**

Protocol Engineering Challenges

- The execution of a protocol may proceed in many different ways, e.g. depending on:
  - Whether messages are lost during transmission.
  - The scheduling of processes (protocol entities).
  - The time at which input is received from the environment.
- Protocols often exhibit complex behaviour and have an infinite number of possible executions:
  - It is easy for the protocol engineer to miss important interaction patterns during design.
  - This may lead to gaps or malfunctions in the protocol design.
  - Makes testing and debugging difficult.

Concurrency

Non-determinism

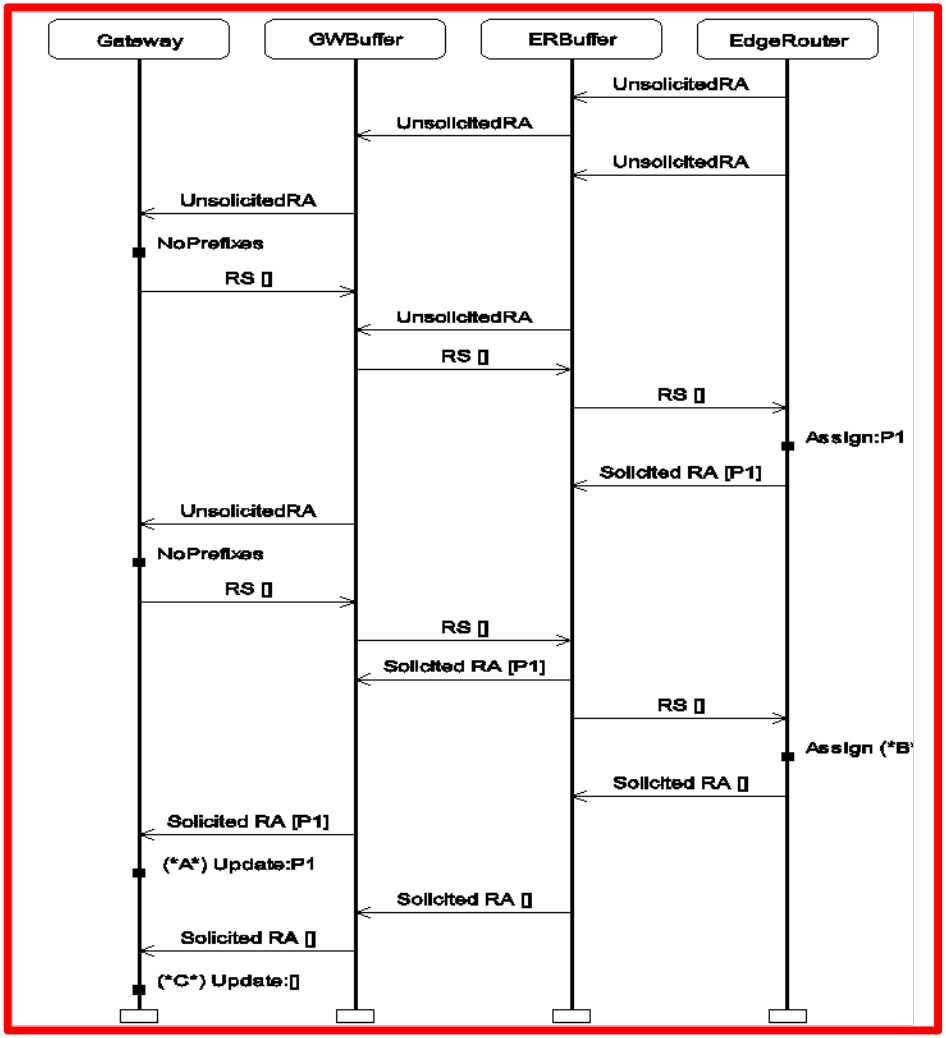
Example: ERDP Protocol

ERICSSON

- **Protocol for gateway configuration in mobile ad-hoc network:**

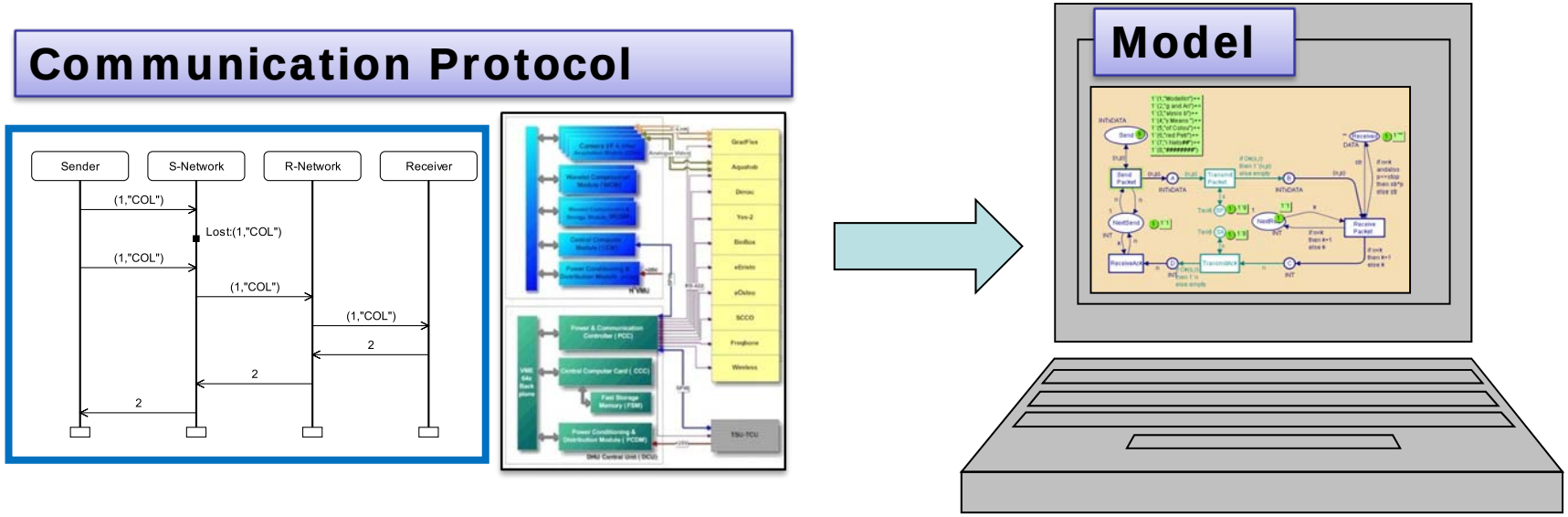
Edge router **Gateway**

- **Combination of message loss and scheduling:**
  - **Inconsistent configuration.**
  - **Livelocks.**



Specification of Protocols

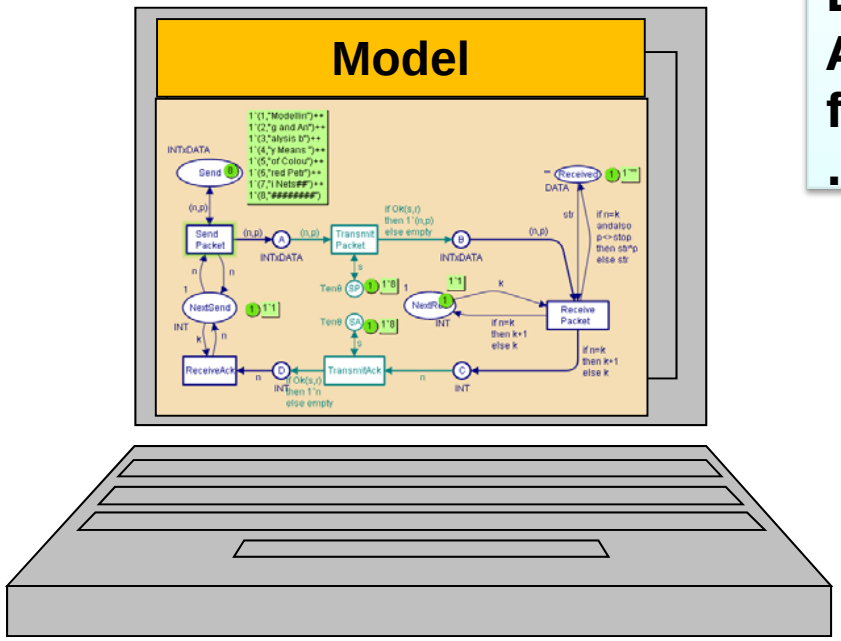
- **Based on the construction of formal executable models that can be analysed by computer tools:**



- **Modelling is beneficial for insight, completeness, and correctness of the protocol design.**

From Models to Verification

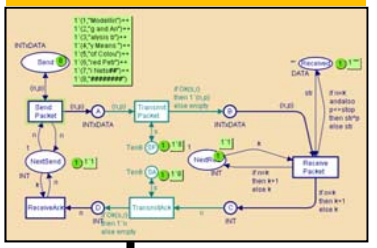
- We would like to verify (guarantee) that the protocol is correct (has the desired properties).



Properties (questions)

Deadlock free?
A request is always followed by a response?
....

Model

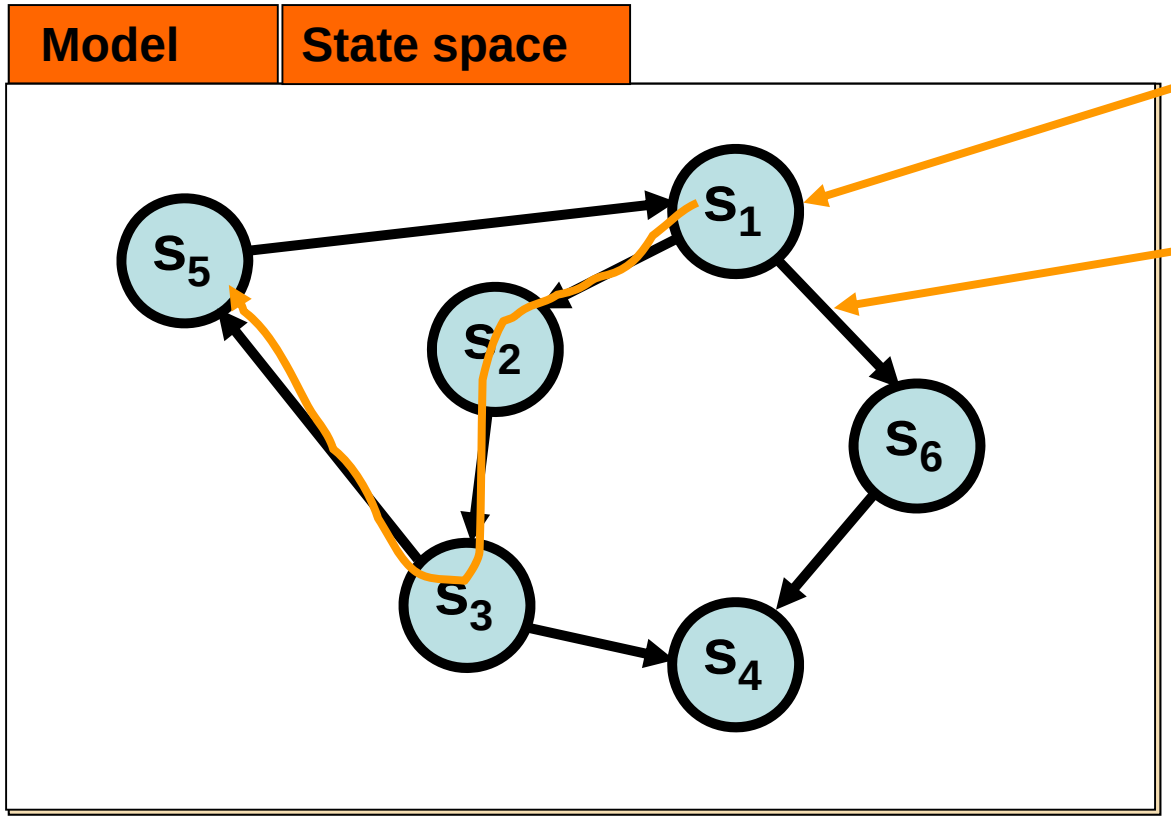


Model Checking Computer Tool

Answers [yes / no,...]

State Space Methods

- One of the main approaches to **verification** of communication protocols:



Nodes ➔
set of reachable states

Arcs ➔
occurrences of events

Paths ➔
Set of execution sequences

Guarantees complete coverage of executions:

Systematic error detection

+ Verification

Main challenge:

State explosion problem

Outline [www.hib.no/ansatte/lmkr/acpn2010/]

- **Introduction to state space-based verification methods and model checking techniques. [WP]**
- **Formal modelling of protocols:**
  - Petri Nets and Timed Automata. [WP]
  - Hierarchical Coloured Petri Nets and CPN Tools. [LMK]
- **Model checking and verification of protocols:**
  - Bounded Parametric Model Checking for Petri Nets. [WP]
  - Explicit state space exploration of Coloured Petri Nets. [LMK]
- **Examples of case studies and application of computer tools for modelling and verification:**
  - **The VerICS Toolkit**: A selection of smaller case studies. [WP]
  - **CPN Tools**: Edge Router Discovery Protocol and the Generic Access Network Architecture. [LMK]

Classical References

- G.J. Holzmann: Design and Validation of Computer Protocols, Prentice Hall, 1991.
- J. Billington, M. Diaz, G. Rozenberg (Eds): Application of Petri Nets to Communication Networks, LNCS 1605, 1999.
- M.T. Liu: Protocol Engineering, Advances in Computers, Academic Press, pp. 79-195, 1989.
- A. Valmari: The State Explosion Problem. Lectures on Petri Nets I: Basic Models, LNCS 1491, pp. 429-528, 1998.