Verification of the Session Management Protocol

Master's Project in Computer Science

Karl Palmskog

Supervisor: Mads Dam
Examiner: Johan Håstad
Commissioned by Yuri Ismailov at Ericsson AB

2006-11-08

Session Layer Resurgence

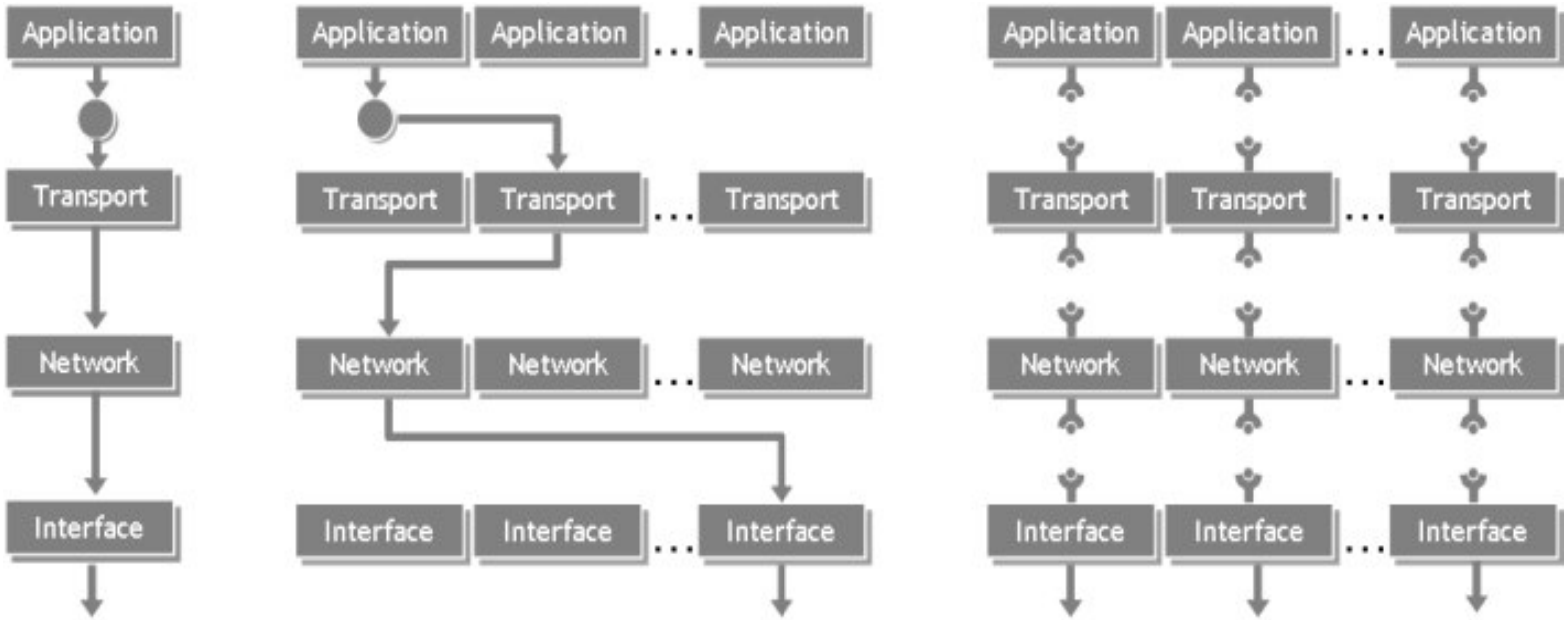
Problem situation

- Demand for new network services
- Aging Internet architecture
- Need to handle mobility and nomadicity
- Lots of extensions of TCP/IP: MIP, HIP, IPSec, ...

Proposed solution

- Adopt a more flexible view of the protocol stack
- Introduce new functionality at the session layer
- Use event-driven reconfiguration and state management

Session Layer Resurgence

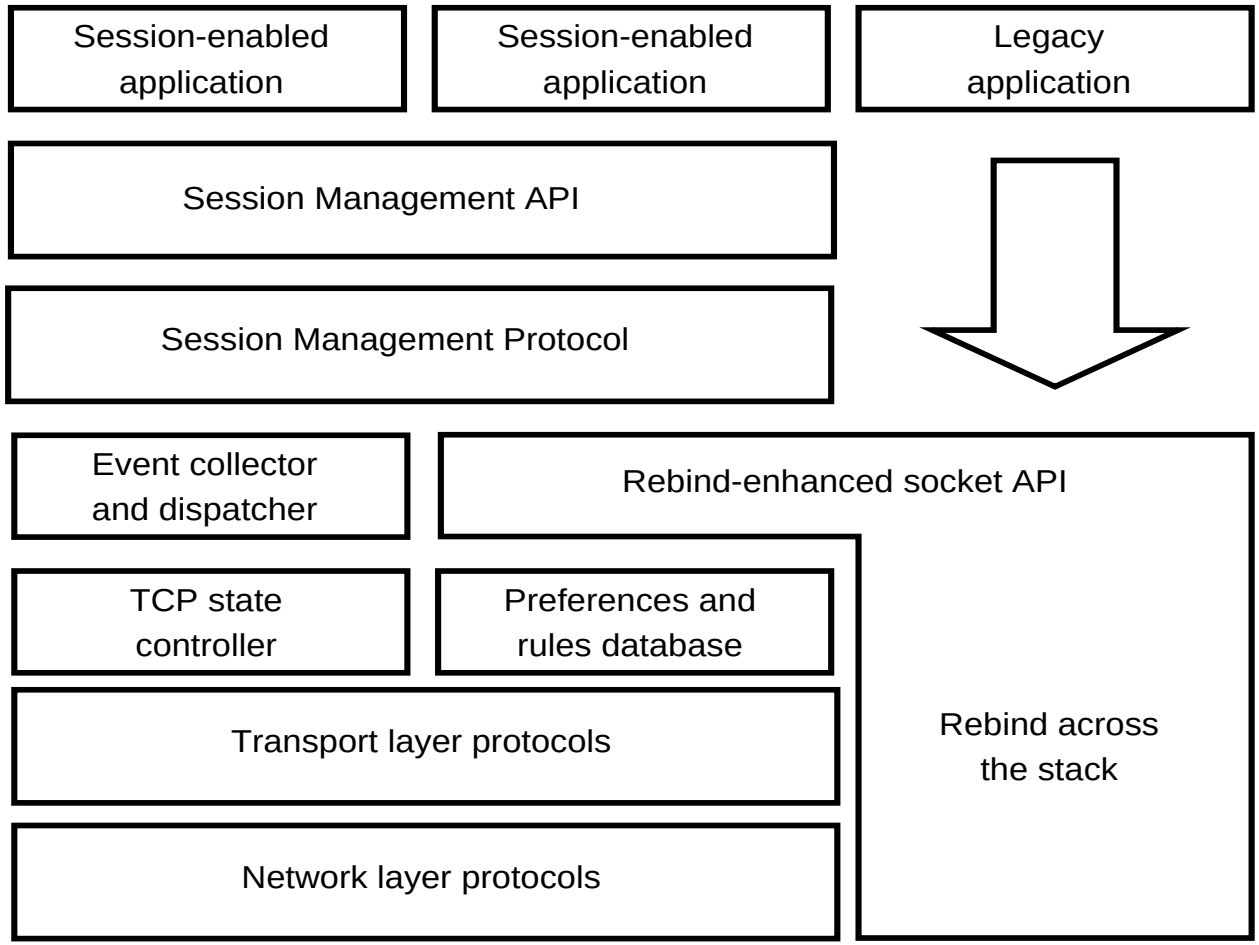


Session Layer Resurgence

Session layer components

- Event collector/dispatcher
- Preferences/rules database
- Socket rebind extension
- Session API
- TCP state controller
- Session Management Protocol (SMP)

Session Layer Resurgence



Session Layer Resurgence

Session Management Protocol

- Data integrity for sessions
- Keep track of communication state
- Send and and receive context updates

Background

- Developed as a part of an earlier master's project
- Proof-of-concept implementation in the Linux kernel
- Vital part of the session layer

Problem and aim

Problem

- SMP correctness is critical
- Data integrity must be preserved
- Design must be deadlock-free

Aim

1. Understand SMP and describe it formally
2. Specify the correctness of the protocol
3. Prove that the protocol satisfies the specification

Method

Model checking

- Provide system model M, specification Φ
- Check automatically whether M satisfies Φ
- Use abstraction to reduce state space

Choices

- Modelling language: PROMELA
- Specification language: Linear Temporal Logic
- Model checker: SPIN

Session Management Protocol

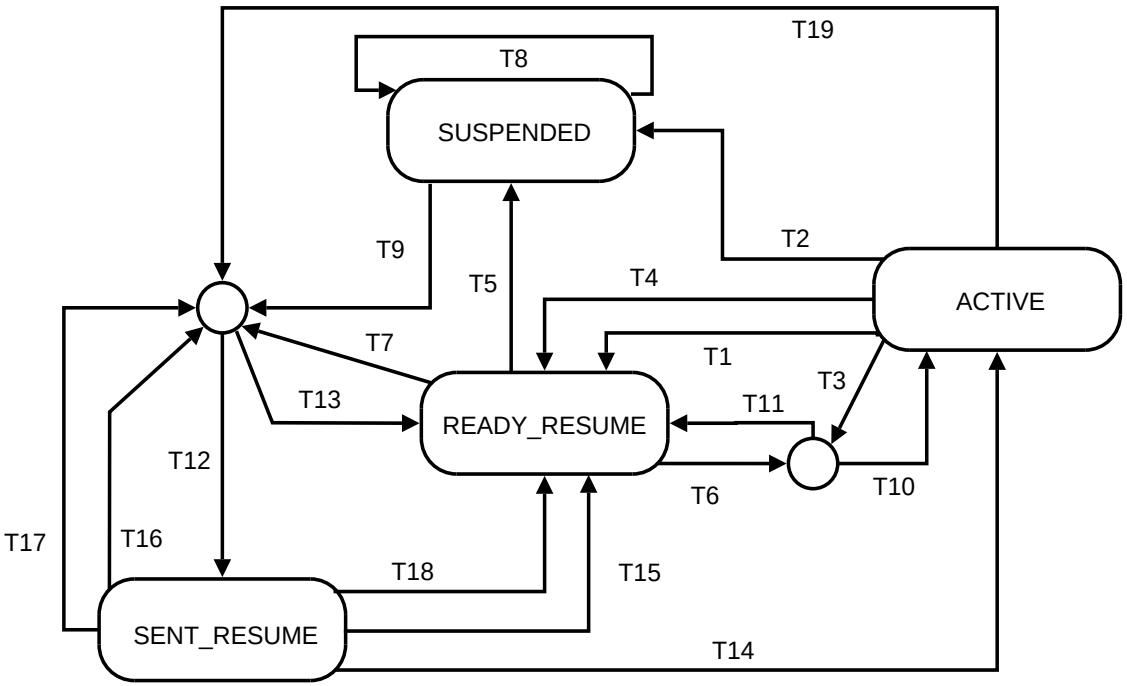
SMP service provisions

- Provide reliable data transfer between endpoints...
- ...despite intermittent connectivity in both space and time

SMP channels and message types

- Data channel
  - *data* — application data
  - *checkpoint* — communication state data
- Control channel
  - *resume* — request session resumption
  - *resume_ok* — confirm session resumption
  - *resume_denied* — deny session resumption
  - *suspend* — sender has suspended

State machine



T1: Network lost
T2: User suspends; send suspend
T3: Received resume; rebind
T4: Received suspend
T5: User suspends
T6: Received resume
T7: Network changed
T8: Received resume; send resume_denied
T9: User resumes
T10: Sent resume_ok; rollback
T11: Failed to send resume_ok
T12: Sent resume
T13: Failed to send resume
T14: Received resume_ok
T15: Received resume_denied
T16: Network changed; rebind
T17: Received resume; initiator
T18: Received resume; not initiator
T19: Network lost; change interface

Results

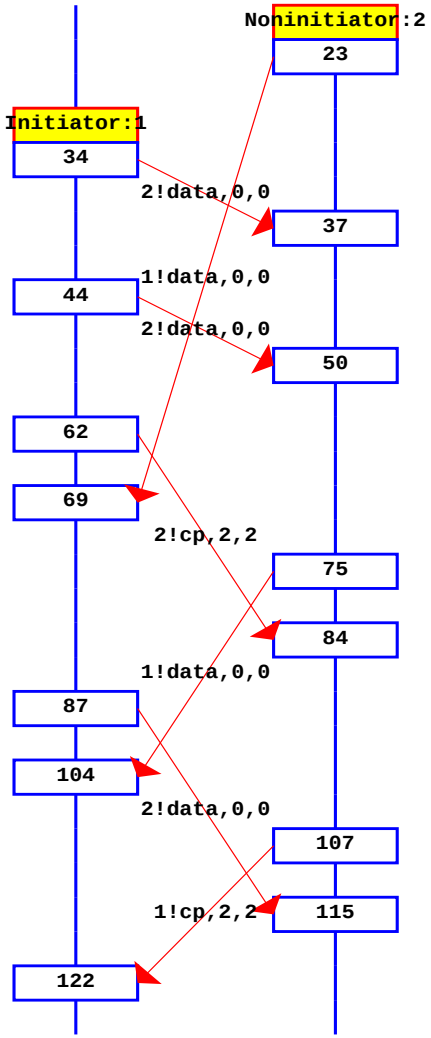
Verification of the checkpoint mechanism

- Lets network endpoints agree on resumeable states
- Endpoints send *checkpoint* messages when buffers fill up
- Cannot create new checkpoint until other endpoint responds
- Specification: processes always have a common checkpoint

Design flaw

- A *checkpoint* request can be interpreted as a response
- Possible to get ambiguously defined states in some situations
- Solution: only allow one endpoint to send checkpoint requests

Results


Noninitiator:2
23
Initiator:1
34
2!data,0,0
37
1!data,0,0
44
2!data,0,0
50
62
69
2!cp,2,2
75
84
1!data,0,0
87
104
2!data,0,0
107
1!cp,2,2
115
122

Results

State machine correctness

- Safety: if a session is resumed, it is resumed properly
- Liveness: there are no deadlocks

State machine model

- Add control channels and states to checkpoint model
- Use PROMELA's channel over channel feature for mobility
- Protocol changes due to changes in the checkpoint mechanism

Verification results

- Exhaustively verified for some parameters
- Many partial state-space searches

Conclusions and future work

Conclusions

- Produced unambiguous specification of the protocol
- Detection and correction of a design flaw
- SMP reliability has increased

Future work

- Implement changes and test them
- Verify other parts of the session layer design
- Investigate SMP/TCP interaction

> *"Every protocol should be considered incorrect until the opposite is proven."*
> —*Gerard J. Holzmann, author of* SPIN

More information

Protocol models and thesis available at:
`http://www.palmskog.net/exjobb`

Session Layer Resurgence: Towards Mobile, Disconnection- and Delay-tolerant Communication. Accepted to the 4th European Conference on Universal Multiservice Networks (ECUMN'2007), February 2007.
`http://www.irit.fr/ecumn07`