University of Twente
The Netherlands

# Performance evaluation of a Transport System supporting the MobiHealth BANip: Methodology and Assessment

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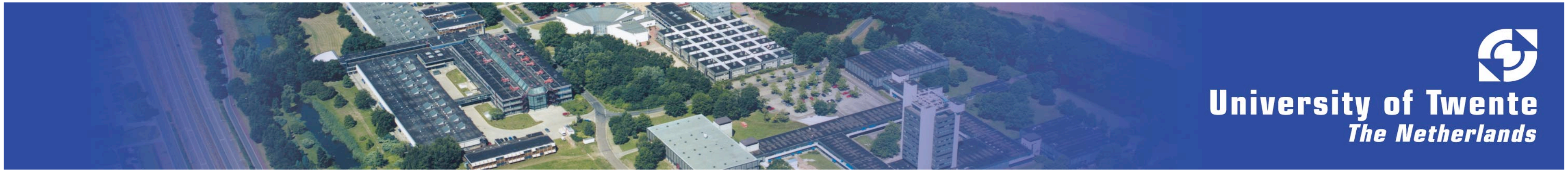
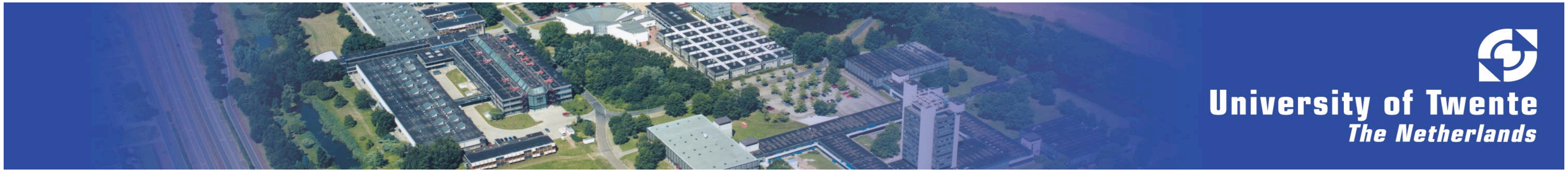



# Presentation layout

- Introduction
  - MobiHealth project, MobiHealth system
- Problem description
  - End-user requirements, MobiHealth transport system, research question
- Approach
  - MobiHealth transport system performance evaluation methodology, methodology outline (speaker switch)
- Conclusions
  - Supported end-user requirements, MobiHealth system recommendation

# Introduction




# MobiHealth project

- MobiHealth was an European project that explored the possibilities of GPRS and UMTS mobile communication (transport) systems to support emerging m-health services
- Service delivered by the MobiHealth system is a m-health service instantiation
- How does the MobiHealth system work?
  - Service platform
  - System components
  - BAN interconnect protocol (BANip)

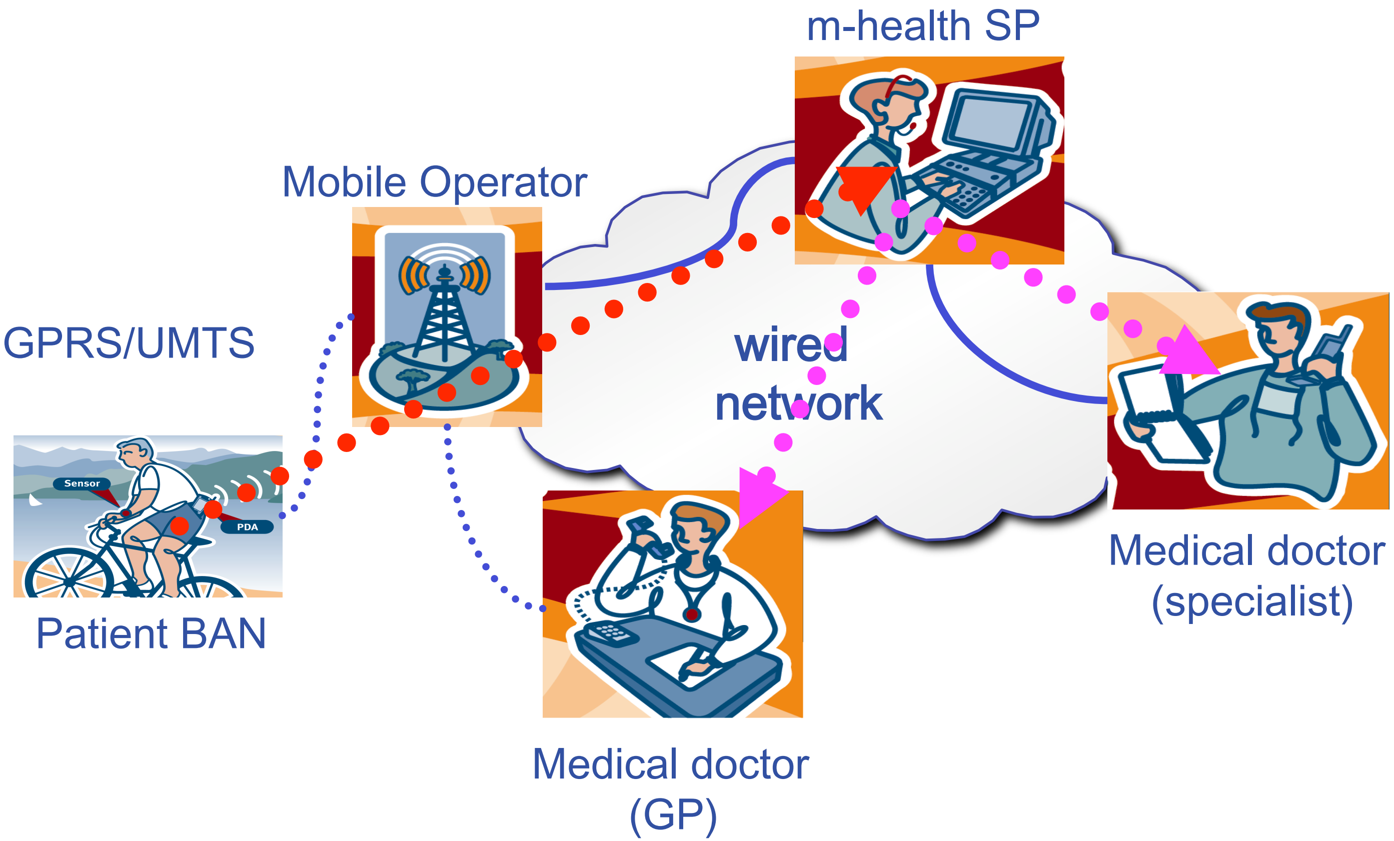
MOBIHEALTH



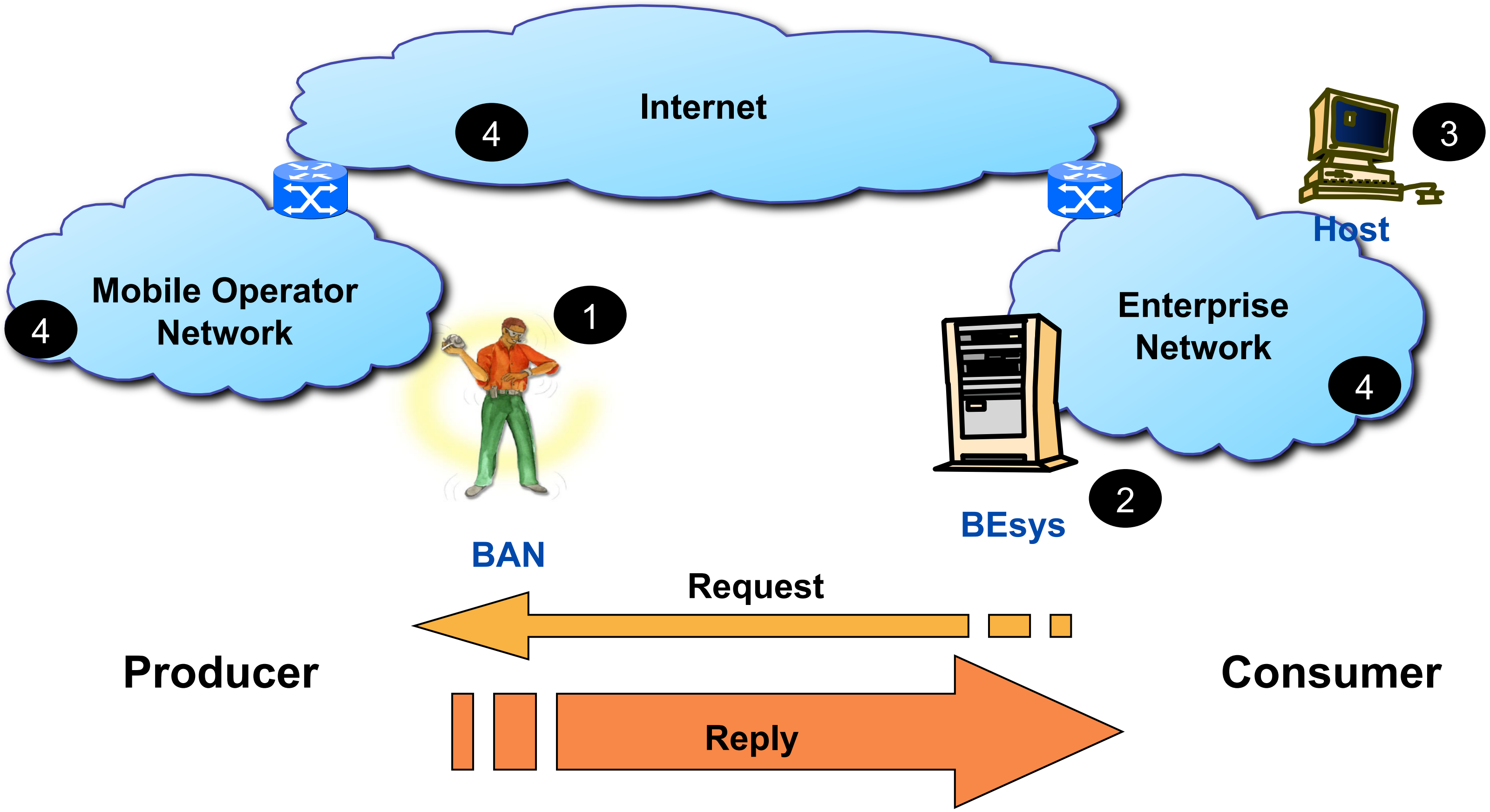
# Service platform

- Offers a m-health service set to end-users in the healthcare domain
- Service set (m-health SP)
  - Alarm service
  - Content service (incl. streaming)
  - Monitoring service (ambulatory) ← focus
- End-user roles
  - Patient
  - Trained nurse and paramedic
  - Medical doctor

# Operational overview



# System components



# BAN

- Wireless sensor system
  - vital signs measurements
- Mobile Base Unit
  - measurements processing
  - intra- and extra-BAN communication
- Wireless communication gateway

# BEsys

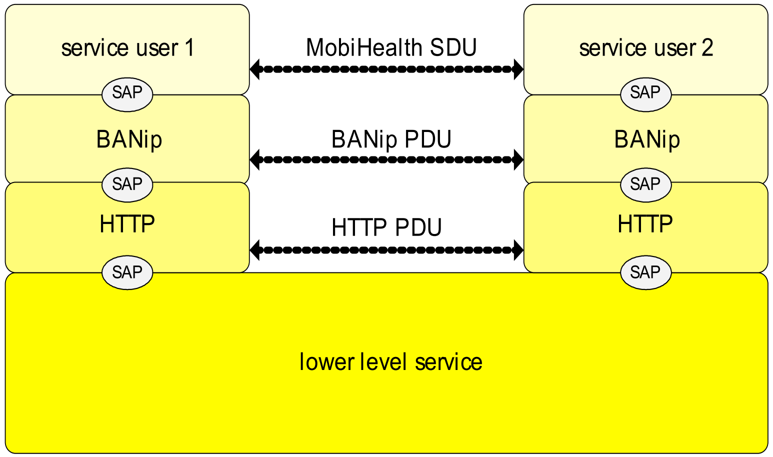
- Authentication and authorization (proxy webserver)
- Secure data transmission (proxy webserver)
- BAN management and control
- Content provisioning (offline, online)

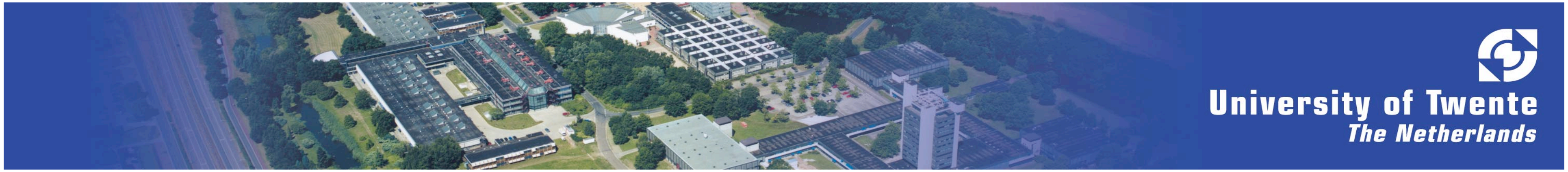
# Host

- PortiLab 2: vital signs visualization/interpretation

# BANip

- Special purpose TCP/IP-based application protocol to support communication between wireless BANs (i.e. MBU) and a wired BEsys
- Runs on top of HTTP: supported by mobile operators



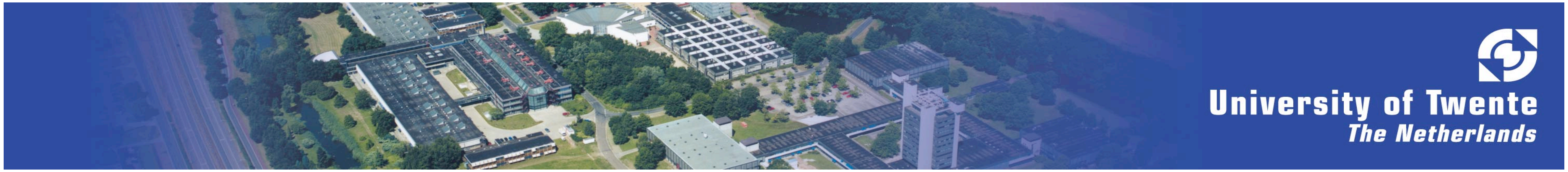



# Problem description

# End-user requirements

- MobiHealth service set selection
  - Monitoring service (MobiHealth trials)
- End-user requirements <u>not</u> defined
  - No vital sign sample frequency specified
  - No maximum vital sign sample delay specified (e.g. realtime or non-realtime?)
  - No maximum vital sign sample delay variation specified
- Conclusion:

  MobiHealth monitoring service is a <u>best-effort</u> service




# MobiHealth transport system

- BANip SDU exchange service must support the best-effort monitoring service
- Lower Level Service must support required BANip "QoS"
- Lower Level Service is a transport service delivered by the MobiHealth transport system
- MobiHealth transport system is implemented as a reliable UMTS based communication system with restricted resources



# Conclusion

- MobiHealth monitoring service is a best-effort reliable service
- BANip SDU exchange service and MobiHealth transport service must fulfill the best-effort reliable service requirement
- MobiHealth transport system implementation:

  TCP/IP on top of a UMTS based transport system

Research question:

How to derive the best possible quality of service of the selected MobiHealth transport system?

# Approach

# MobiHealth transport system performance evaluation methodology

Note: Dedicated (pre) commercial UMTS transport sub-system available → performance measurements is an option!

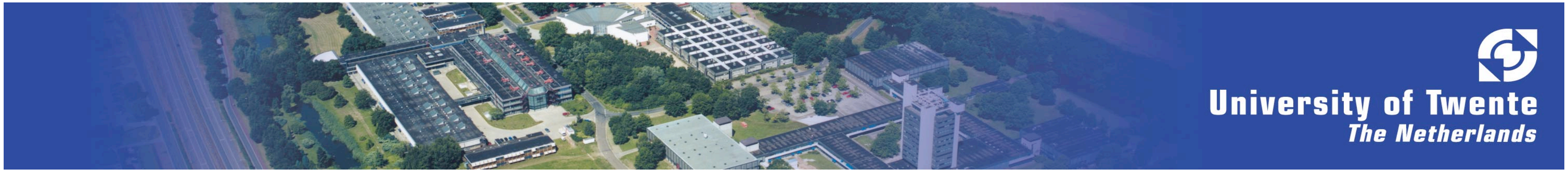
- Development of a generic measurements-based performance evaluation methodology
- Design and implementation of a distributed performance evaluation system containing workload generators and measurement functions
- Design and implementation of a basic statistical application



# Performance evaluation methodology

| | |
|---|---|
| 1. State the Goals and System Definition | |
| 2. List Services and their Outcomes | |
| 3. Select Performance Criteria (i.e. Metrics) | |
| 4. List System and Workload Parameters | |
| 5. Select Factors and their Levels | |
| 6. Select System and Workload Parameters | |
| 7. Design and Execute the Experiments | |
| 8. Analyse, Evaluate and Interpret the Data | |
| | a. Select Model Representation |
| | b. Parameterise the Model |
| | c. Validate and Verify the Model |
| 9. Present the Results | |

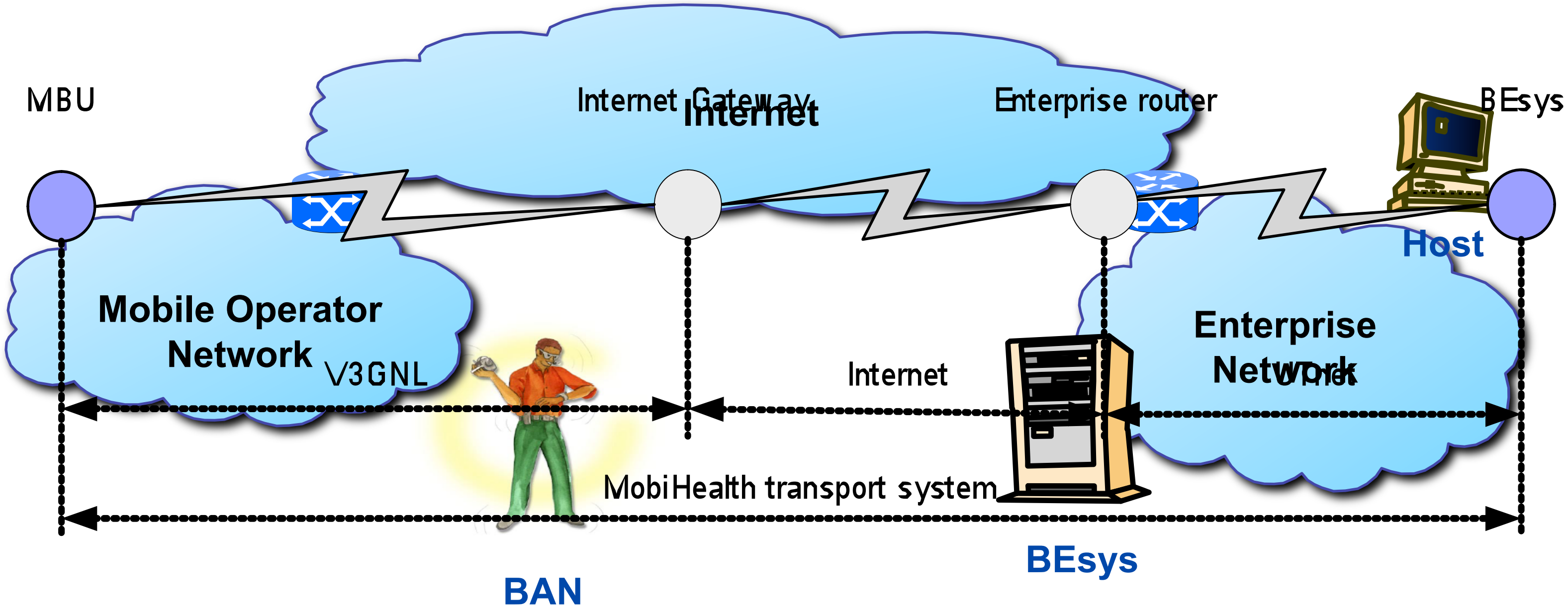
- Preparation: sequential execution of phases 1-6 (reflection!)
  - Must result in precise description of measurements experiments
- Execution: Phases 7-8 (time consuming activities!)
- Assesment and presentation: Phases 8-9



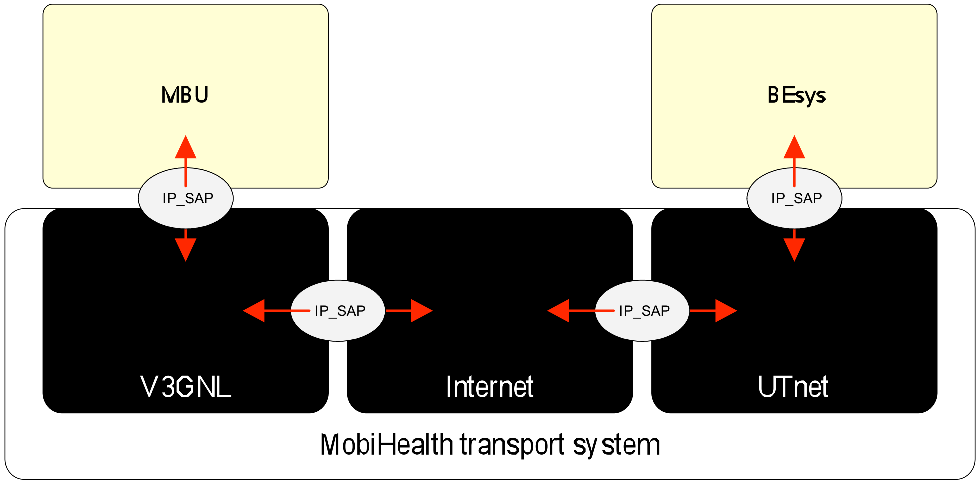

# Methodology phase 1

- State the Goals
  - Characterize the quantitative behavior of a MobiHealth UMTS based transport system
  - Determine the optimal BANip PDU size and PDU rate for a specified (maximum) delivery time
  - Determine if the PDU size of the current BANip implementation is chosen wisely
- System Definition
  - V3GNL (system of interest)
    - MobiHealth (IP based) transport system decomposition
    - “Black box – white box” model
    - SoD and SUT ← focus

# MobiHealth transport system decomposition

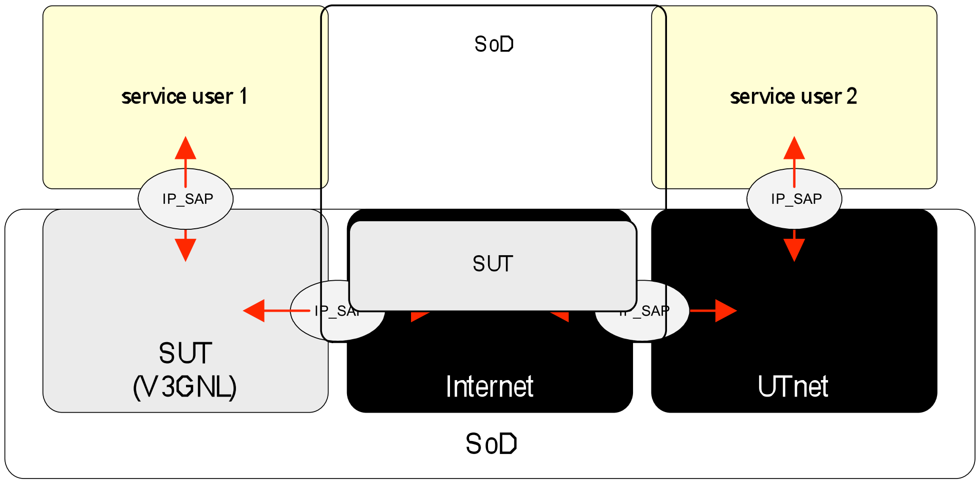


# “Black box – white box” model



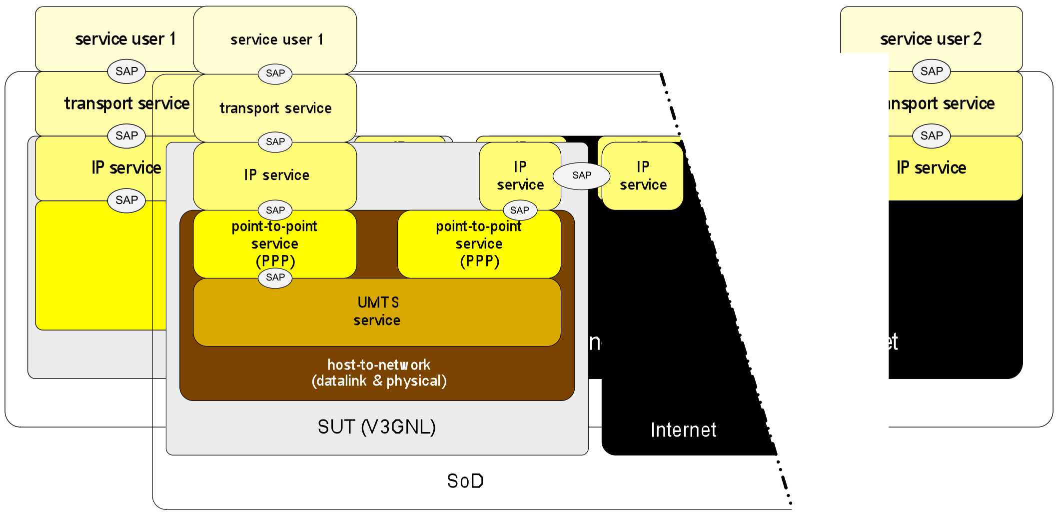
# SoD and SUT

- System of Discourse: reliable MobiHealth (IP based) transport system
- System Under Test – V3GNL



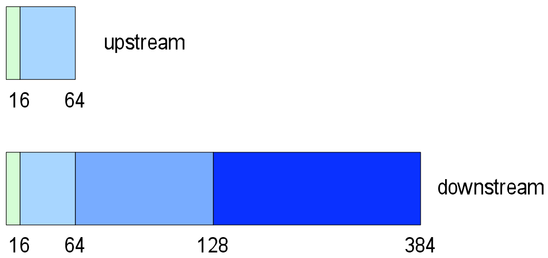
# Methodology phase 2

- List Services and their Outcomes
  - SoD/SUT service decomposition needed!
    (Recall: SoD delivers a reliable transport service)



# Methodology phase 2 (cont.)

- List Services and their Outcomes
  - SoD
    - Service is available
    - Service is dependable and accurate
      - TCP service (no loss of data, no data corruption)
  - SUT
    - IP datagram service
    - Asymmetrical service with different uplink and downlink transport capacity
    - Transport service capacity correlates to volume and rate of uplink and downlink datagrams



# Methodology phase 3

- Select Performance Criteria (i.e. Metrics)
- ITU-T 3x3 matrix approach
  - Performance evaluation goals are speed-related:

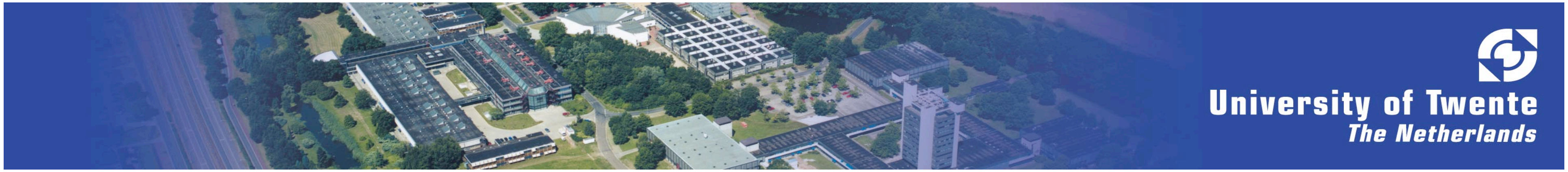
    Speed is the performance criterion that describes the delivery time that is used to successfully perform a transfer function and the rate at which this transfer is performed

| performance parameter / performance criterion | delay | jitter | goodput |
|---|---|---|---|
| speed | *primary* | *derived* | *derived* |



# Methodology phase 4 & 5

- List System Parameters and Workload Parameters
- System parameters: system description related parameters; fixed for every performance measurement of a SoD/SUT instantiation
- Workload parameters: parameters for which the effects on the performance measurement can be investigated




# Methodology phase 6

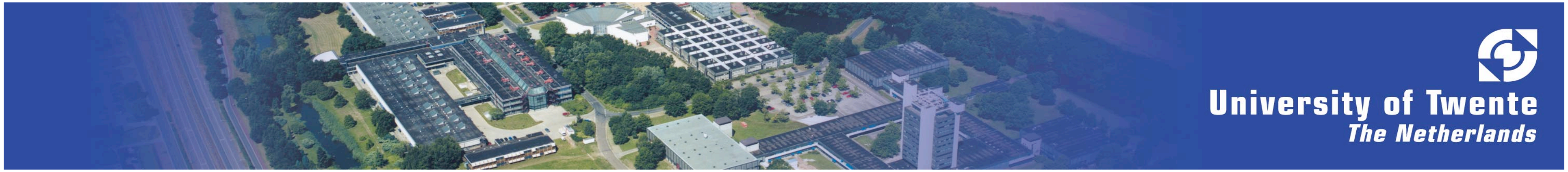
Select

System parameters

and

Workload parameters

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **computer systems** | | nb, pcl | nb, pcl | nb, pcl | nb, pcl, pc2 | iPAQ, pcl | nb, pcl | nb, pcl | nb, pcl | nb, pcl |
| **intra comm.** | | USB | Bluetooth | PCMCIA | USB | Bluetooth | USB | USB | USB | USB |
| **UMTS terminal** | | Nokia 6650 | Nokia 6650 | PC Card | Nokia 6650 | Nokia 6650 | Nokia 6650 | Nokia 6650 | Nokia 6650 | Nokia 6650 |
| **APN** | | utwente.nl | utwente.nl | utwente.nl | utwente.nl | utwente.nl | web.vodafone.nl | utwente.nl | utwente.nl | utwente.nl |
| **buff. sizes: appl.sock** | | 64.64 | 64.64 | 64.64 | 64.64 | 64.64 | 64.64 | 64.64 | 32.64 | 32.32 |
| the SoD instance / work-load par | | **SoD_1** | **SoD_4** | **SoD_5** | **SoD_6** | **SoD_7** | **SoD_8** | **SoD_1** | **SoD_2** | **SoD_3** |
| **Service type** | | Confirmed service | | | | | | Unconfirmed service | | |
| **Sample size**[**] | | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| **Matrix** | | 20x20 | 8x8 | 8x8 | 8x8 | 8x8 | 8x8 | 524 Bytes | 524 Bytes | 524 Bytes |
| **Saturation factor** | 0.5 | | | | | | | x | x | x |
| | 0.6 | | | | | | | x | x | x |
| | 0.7 | | | | | | | x | x | x |
| | 0.8 | | | | | | | x | x | x |
| | 0.9 | | | | | | | x | x | x |
| | 1.0 | | | | | | | x | x | x |
| | 1.1 | | | | | | | x | x | x |
| | 1.2 | | | | | | | x | x | x |
| | 1.5 | | | | | | | x | x | x |
| | 2.0 | | | | | | | x | x | x |
| **No** | 1 | x | x | x | x | x | x | x | x | x |
| | 5 | | | | | x | | | | |
| | 10 | | | | | x | | | | |




# Methodology phase 7

- Design and Execute Experiments

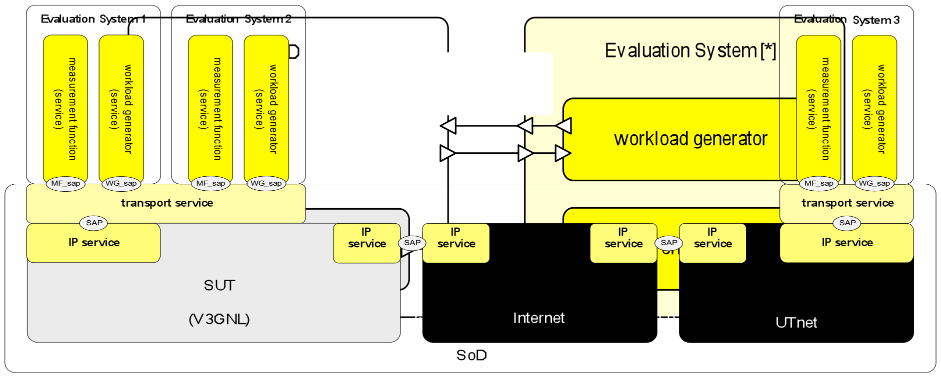
**Experiment 1**

| | | | |
|---|---|---|---|
| TestID | 01 | | |
| APN | utwente.nl | | |
| HOPS | Server <> Client | | |
| Test description | Confirmed Service, 20x20, UMTS-UT/USB, Server/Client, 1 Terminal | | |
| Extra comms | UMTS | | |
| Intra comms | USB | | |
| Clock sync | Tardis 2000 V1.5 | 0.712 seconds/day | ASUS notebook |
| Equipment: | | | |
| Identifier | Name | HW-platform | SW-platform |
| ClientId 01 | Utip194 | P4, 2.4 GHz, 512 MBmem | WindowsXP, JDK 1.3.0 |
| ServerId 01 | Freelander | mP3, 1 GHz, 640MBmem | WindowsXP, JDK 1.3.0 |
| Terminal | Nokia 1 | Nokia 6650 | PR4 |

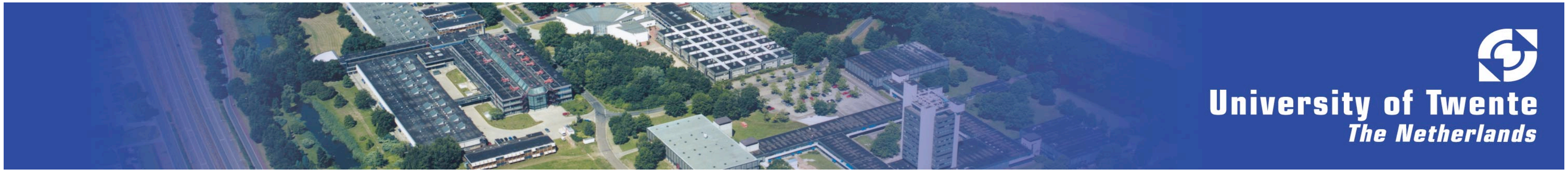
- 11 experiments
- Measurement for each workload parameter repeated 500 times
- 439.000 measurements to perform!

# Methodology phase 7 (cont.)

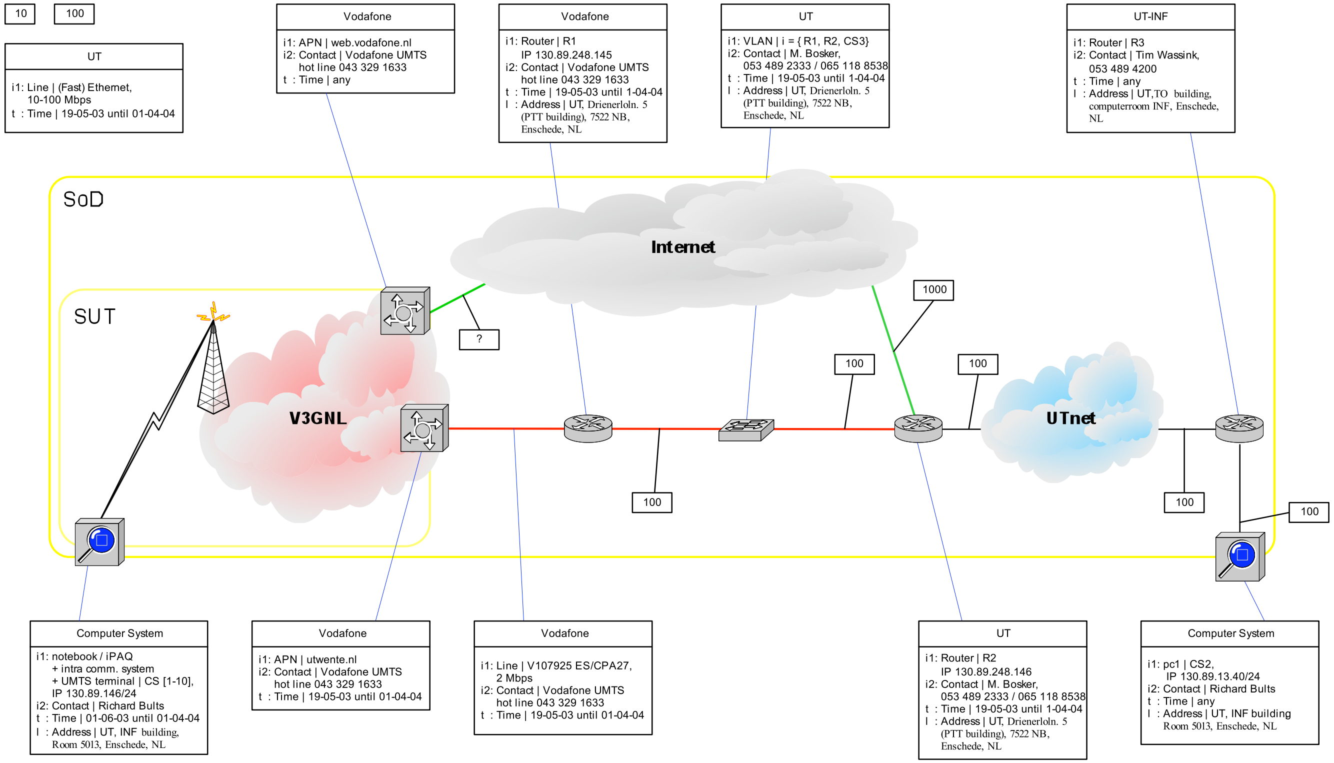
- Need for design and implementation of a distributed evaluation system




functional view
service view




# Methodology phase 7 (cont.)




real-world view

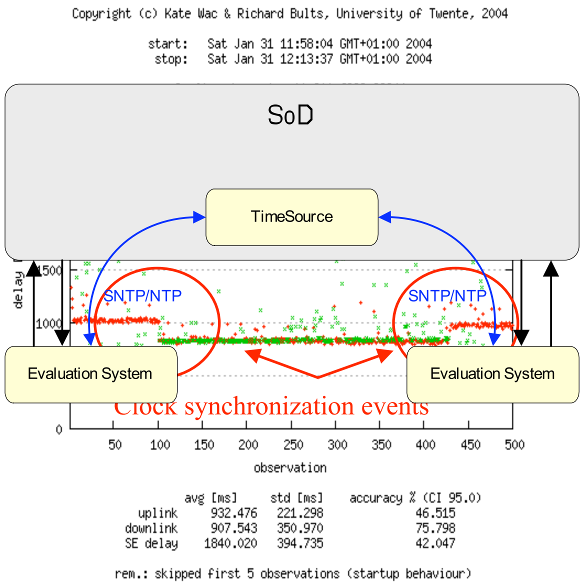
# Methodology phase 8

- Analyze, Evaluate and Interpret the Data

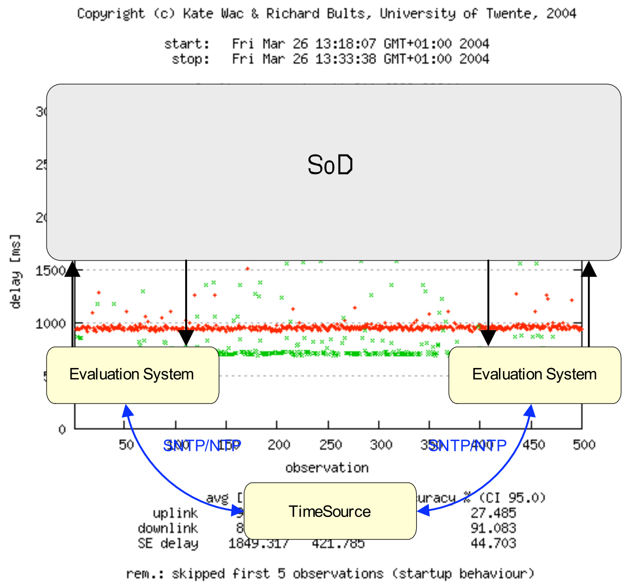
- Need for design and implementation of an basic statistical application
  - Data retrieval and correlation from different evaluation systems
  - Calculation of:
    - uplink, downlink delays
    - delay mean and standard deviation
    - accuracy for 95% confidence interval
  - Visualization of the raw data measurements
  - Storage of the visualized raw data and corresponding statistics

# Methodology phase 8 (cont.)

- Raw data preliminary evaluation: timing events




Inband




Out-of-band

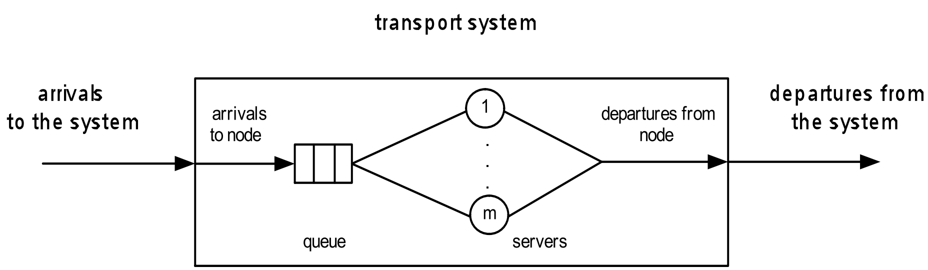
# Methodology phase 8 (cont.)

a. Select Model Presentation
b. Parameterize the model
c. Validate and Verify the Model

Rationale: If no measurements data, a performance model of a benchmark UMTS transport system can be used to determine the application protocol PDU size, rate and a transport delay

# Methodology phase 8 (cont.)

- UMTS transport system simple high-level model
  - Uplink (monitoring service context)
  - PDU size 524 Bytes (1 TCP MSS)
  - Light-load scenario (1 < PDU rate < 12)

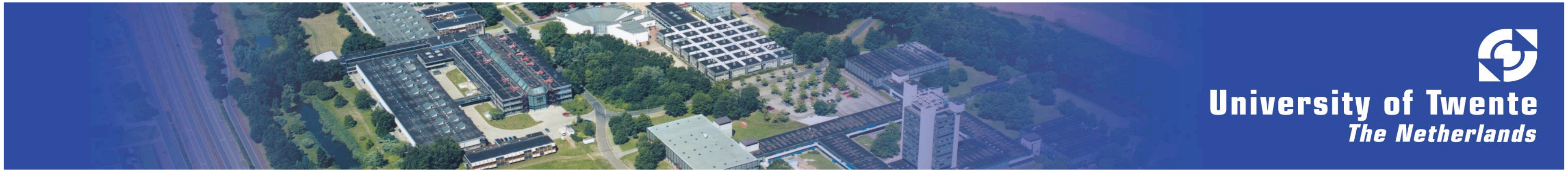



D/G/3
(Deterministic arrival / Generally distributed service time / 3 servers)

# Methodology phase 9

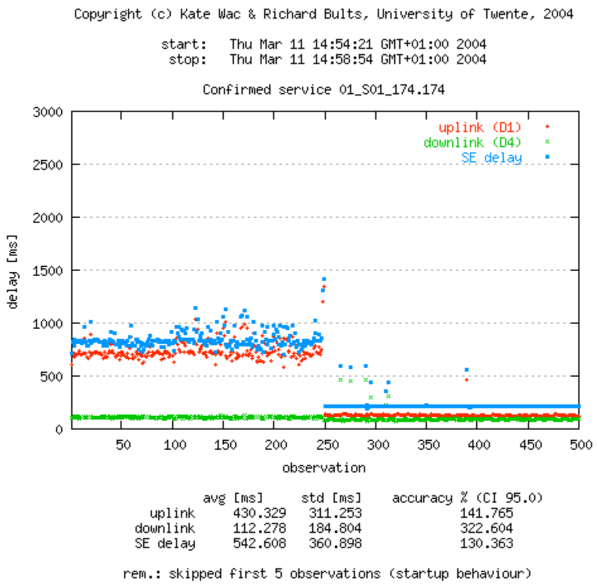
- Present the Results

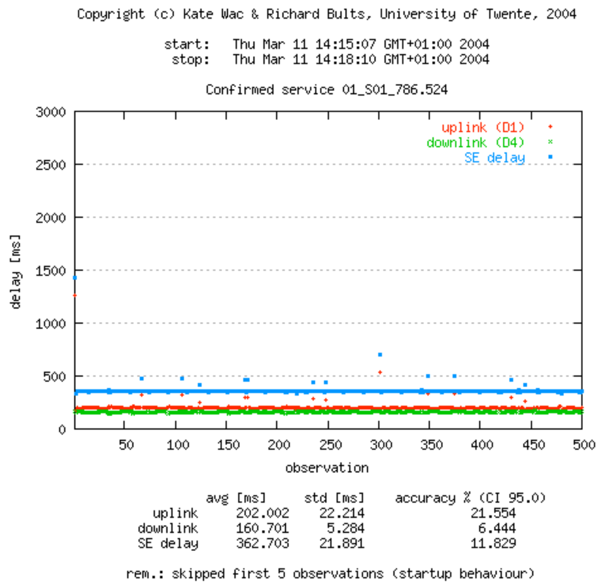
- SUT uplink/downlink behavior
  - Capacity switching behavior
  - Goodput
  - Influence of system parameters
- SUT uplink behavior (monitoring service context)
  - Delay and jitter
  - Scalability characteristics




# Methodology phase 9

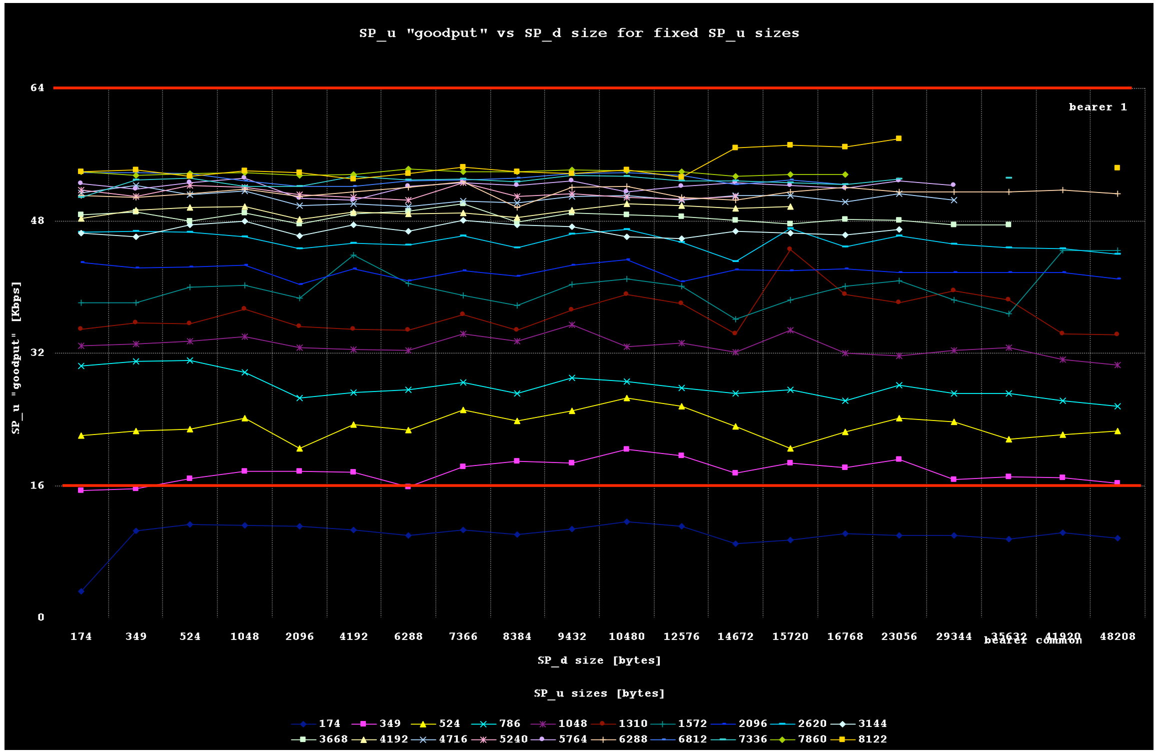
- Capacity switching behavior – uplink

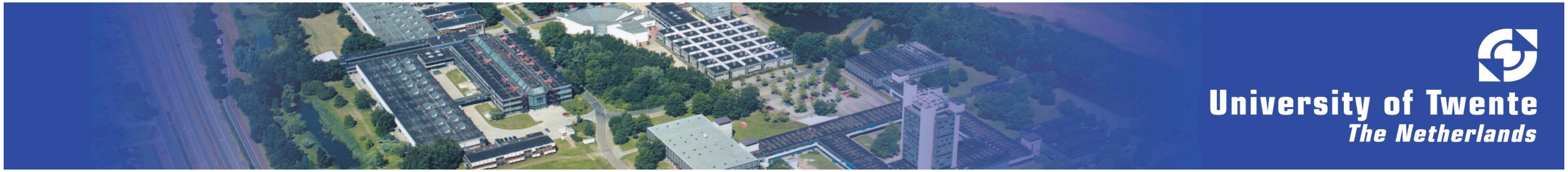


# Methodology phase 9 (cont.)

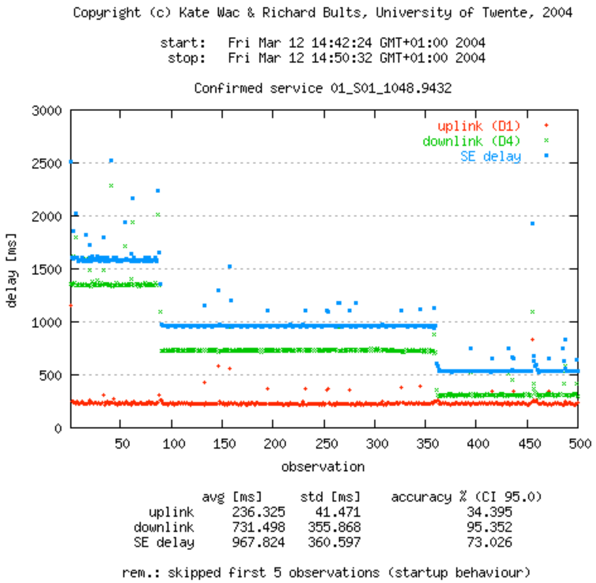
- Influence of downlink behavior on uplink behavior

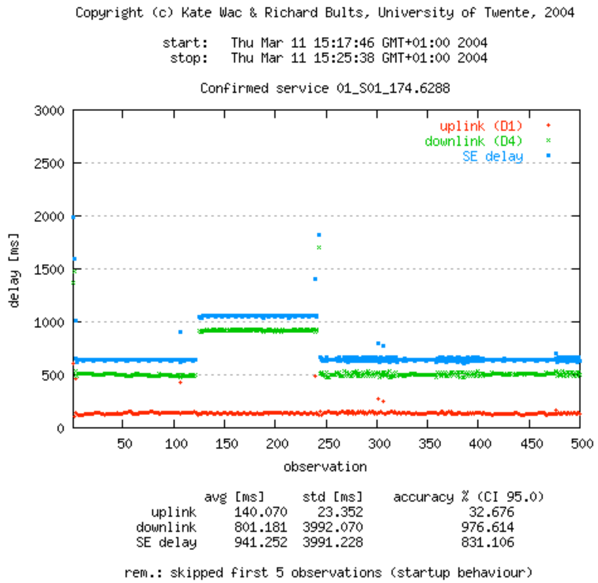


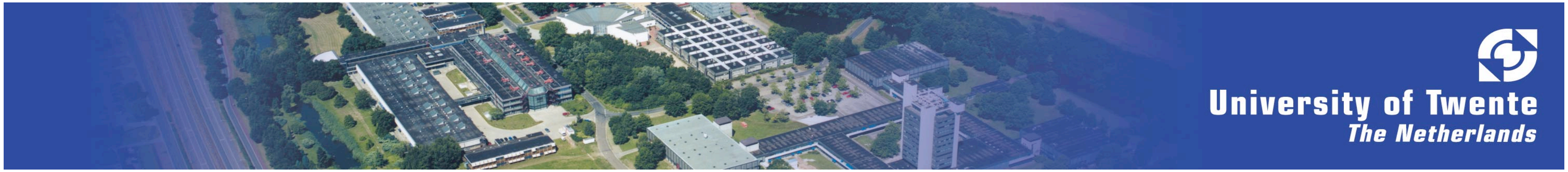



# Methodology phase 9

- Capacity switching behavior – downlink

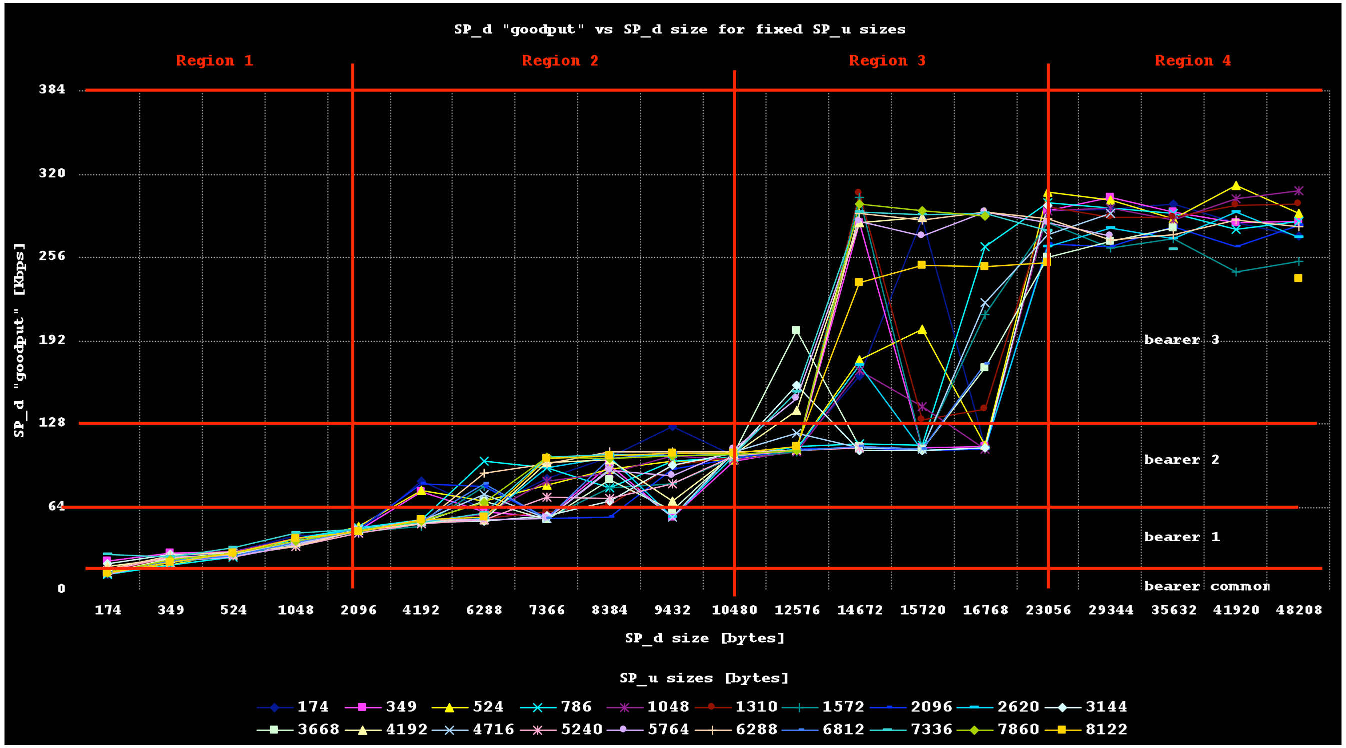





# Methodology phase 9 (cont.)

- Capacity switching behavior - downlink



# Methodology phase 9 (cont.)

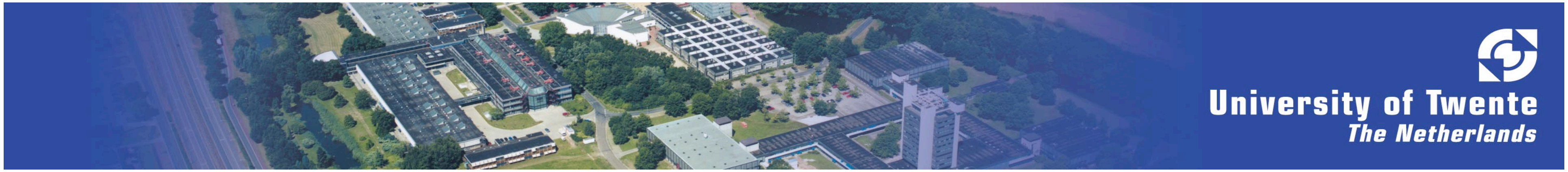
- Capacity switching behavior - conclusion

| | Region 1 | Region 2 | Region 3 | Region 4 |
|---|---|---|---|---|
| **uplink** | data size <= 174 B | data size > 174 B | - | - |
| | common bearer | dedicated bearer 1 | - | - |
| **downlink** | data size <= 2096 B | 2096 < data size <= 10480B | 10480 < data size <= 23056B | data size > 23056 B |
| | common bearer / dedicated bearer 1 | dedicated bearer 1 / dedicated bearer 2 | dedicated bearer 2 / dedicated bearer 3 | dedicated bearer 3 |

# Methodology phase 9 (cont.)

- Goodput – influence of workload parameters

- SUT is a 'goodput bottleneck' system independent of workload (i.e. packet size)
- SUT maximum estimated goodput
  - Uplink : ~ 54 Kbps
  - Downlink : ~ 300 Kbps




# Methodology phase 9 (cont.)

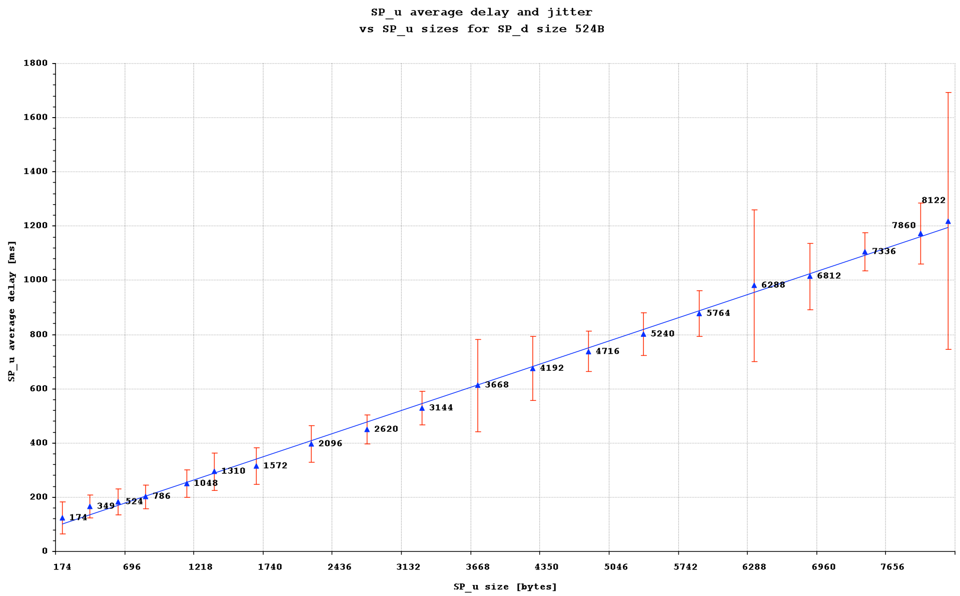
- Goodput - influence of system parameters

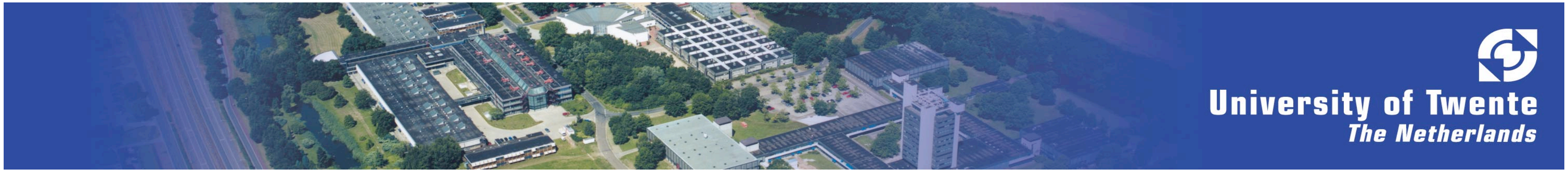
| computer systems | nb, pc1 | nb, pc1 | nb, pc1 | nb, pc1 | nb, pc1 | nb, pc1, pc2 | iPAQ, pc1 | nb, pc1 |
|---|---|---|---|---|---|---|---|---|
| **intra comm.** | USB | USB | USB | Bluetooth | PCMCIA | USB | Bluetooth | USB |
| **UMTS terminal** | Nokia 6650 | Nokia 6650 | Nokia 6650 | Nokia 6650 | PC Card | Nokia 6650 | Nokia 6650 | Nokia 6650 |
| **APN** | utwente.nl | utwente.nl | utwente.nl | utwente.nl | utwente.nl | utwente.nl | utwente.nl | web. vodafone. nl |
| **buff. sizes: appl.sock** [KBytes] | 64.64 | 32.64 | 32.32 | 64.64 | 64.64 | 64.64 | 64.64 | 64.64 |
| the SoD instance | **SoD_1** | **SoD_2** | **SoD_3** | **SoD_4** | **SoD_5** | **SoD_6** | **SoD_7** | **SoD_8** |

- Bluetooth is a downlink goodput bottleneck of 83 Kbps
- No influence of other system parameters

# Methodology phase 9 (cont.)

- Uplink delay = 0.138 * PDU size + 86 [ms]
- Uplink jitter: varies from 6% to 38%
  - SUT bearer assignment (stat. app.)
  - packet loss in one of the SUT subsystems
  - SUT resource problems



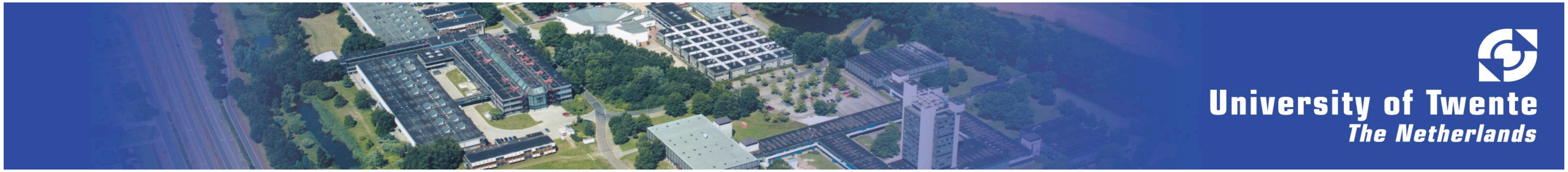



# Methodology phase 9 (cont.)

- Scalability characteristics
- Indicative performance measurements

- Expected: delay and goodput per user must not change significantly when the number of concurrent users per (small) geographical location increases
- Observed: significant SUT performance degradation (delay +100%, goodput -50%) per user for 10 concurrent users scenario

# Conclusions

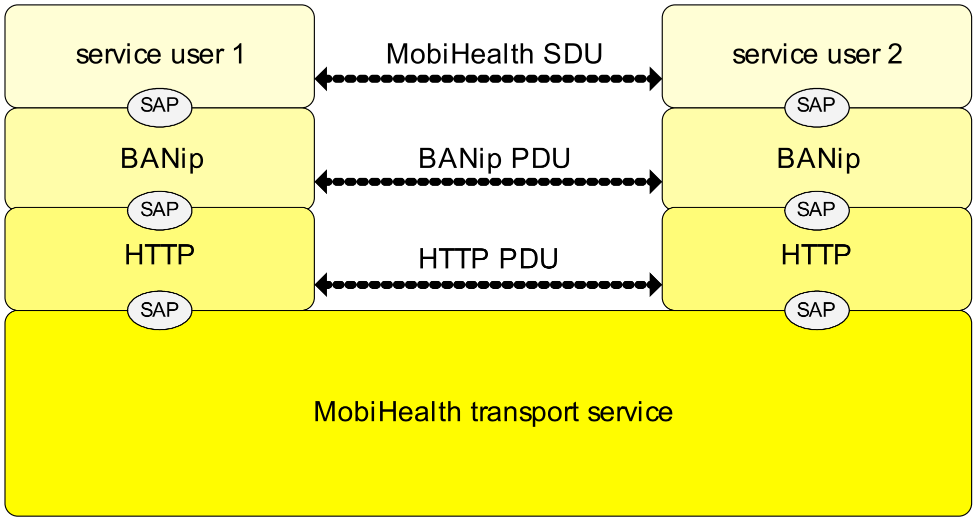



# Research question

- How to derive the best possible quality of service of the selected MobiHealth transport system?

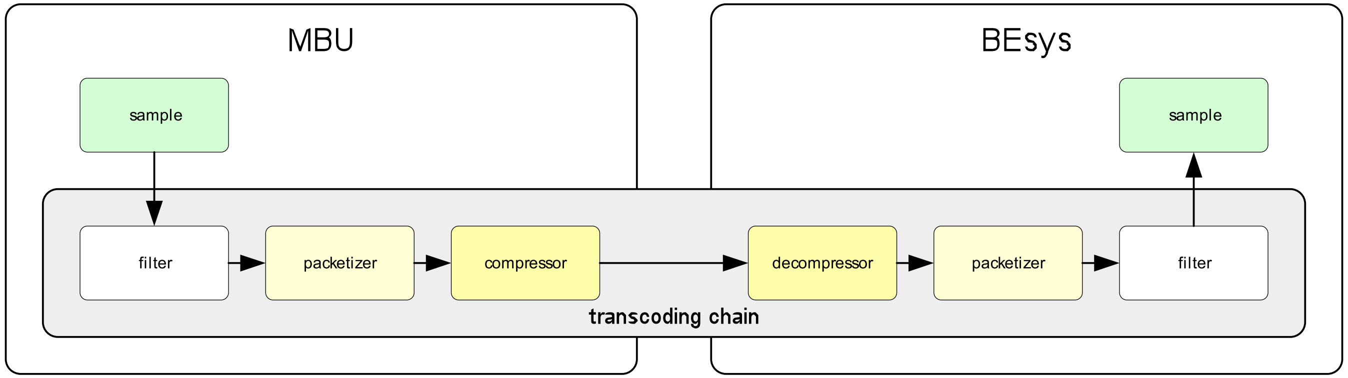
- How to derive it ? - Performance evaluation methodology and assessment
- What is the best possible quality of service delivered to the end-user if a MobiHealth transport system consists of V3GNL, Internet and UTnet?

# BANip SDU exchange service



# MobiHealth SDU

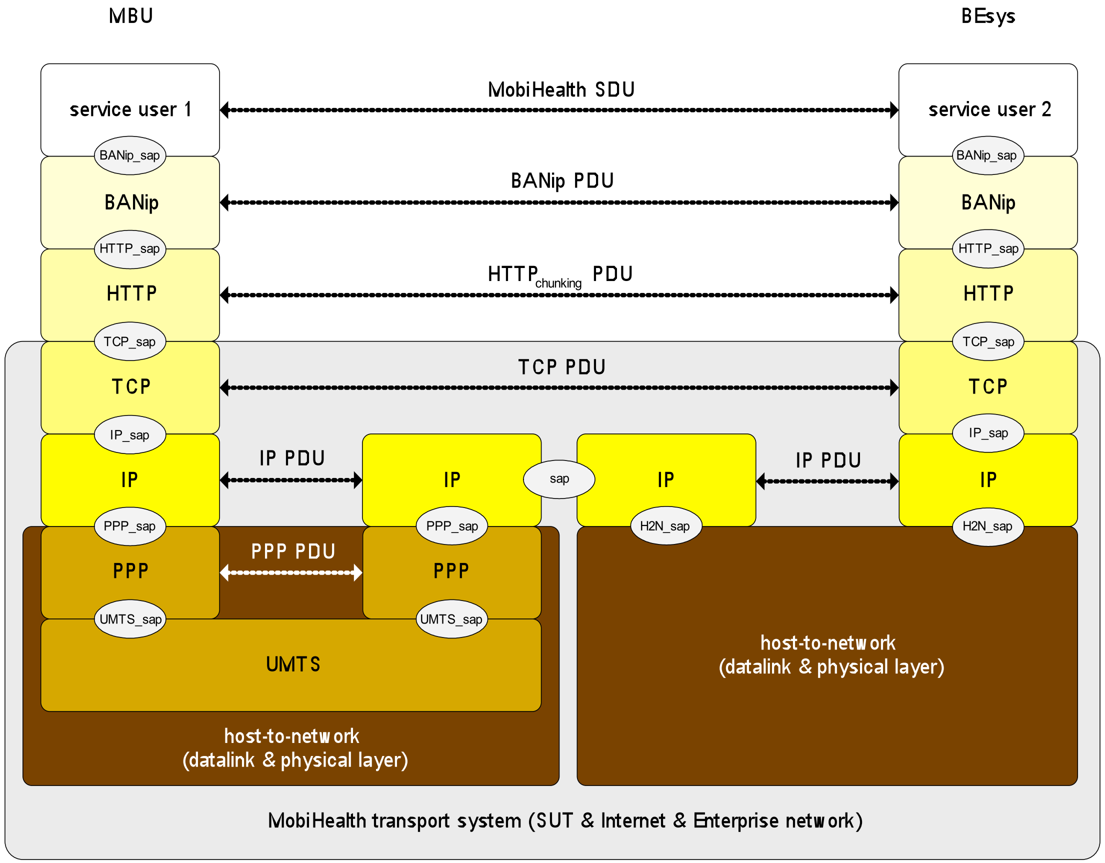
- MobiHealth SDU assembly is part of the BANip transcoding chain
- Transcoding chain consists of
  - Filter
  - Packetizer
  - Compressor/decompressor



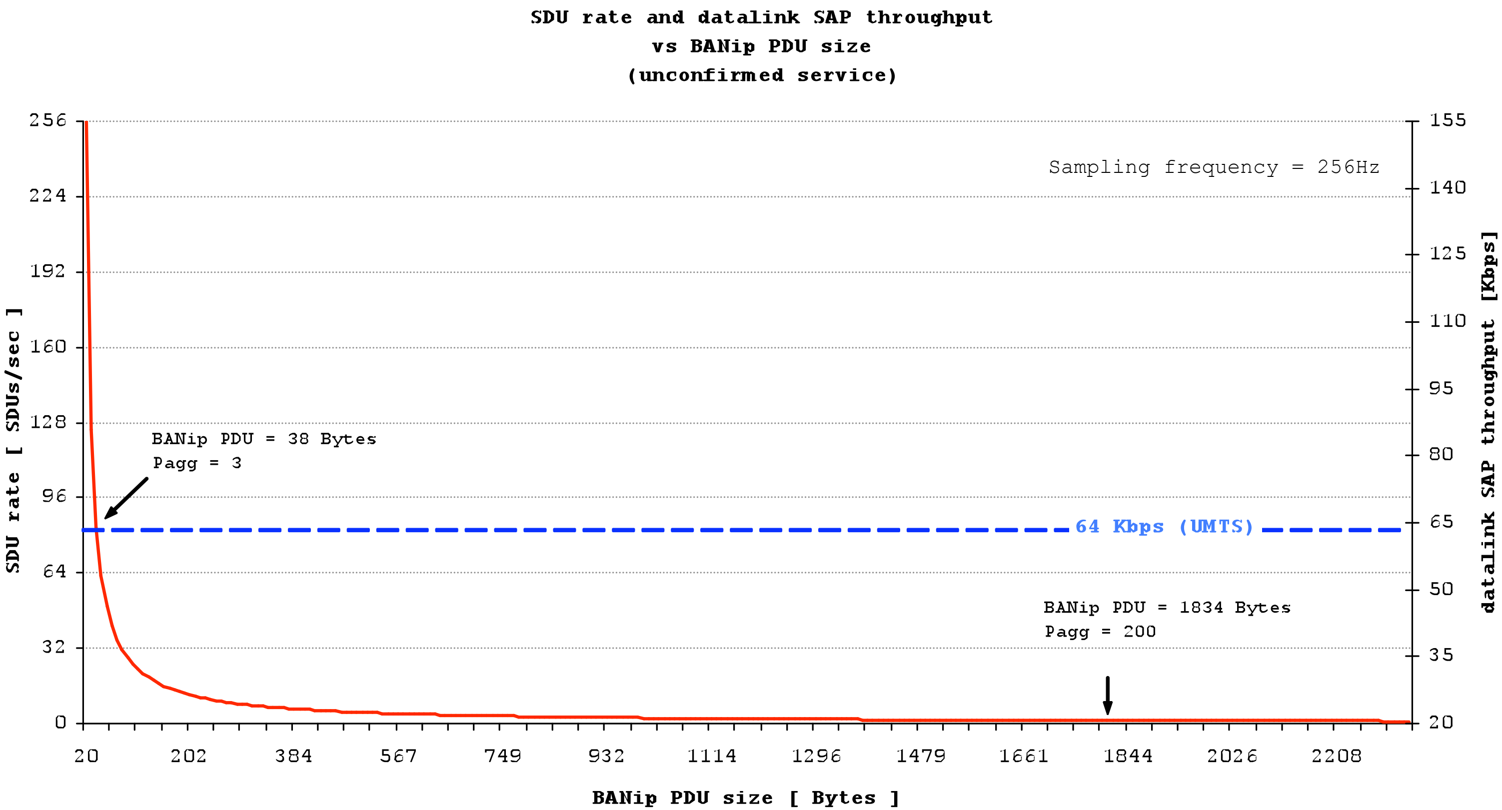
# MobiHealth SDU

- Trauma BAN (Mobi 3e1as)
  - Sampling frequency: 256 Hz
  - Sample size: 19 Bytes
- Transcoding chain
  - Filter: no
  - Packetizer: 1 < Pagg < 255 (MH 200)
  - Compression factor: 52% (for MH 200)
- SDU size = 19 * Pagg * 0.48 (MH 1824B)
- SDU rate = Sampling frequency / Pagg (MH 1.3)

# BANip protocol stack



# SDU rate and UMTS SAP throughput vs BANip PDU size





# Conclusion

- Derived Pagg = 3 and SDU rate = 85
- End-user requirements supported:
  - vital sign sample frequency 256 supported, but…
    - aggregation of >= 3 samples
    - individual sample delay >= **105ms**
  - no maximum vital sign sample delay specified
    - realtime: every sample send at once (Pagg = 1)→ sample frequency 106Hz
- Current MobiHealth implementation supports:
  - vital sign sample frequency 256 supported, but…
    - aggregation of >= 200 samples
    - individual sample delay >= **1123ms**

# Questions
# &
# Answers