Investigation of One-Way Delay Variation in Substrate and Slice Measurements over a European-wide Future Internet Platform

Susanne Naegele-Jackson, RRZE/FAU Erlangen

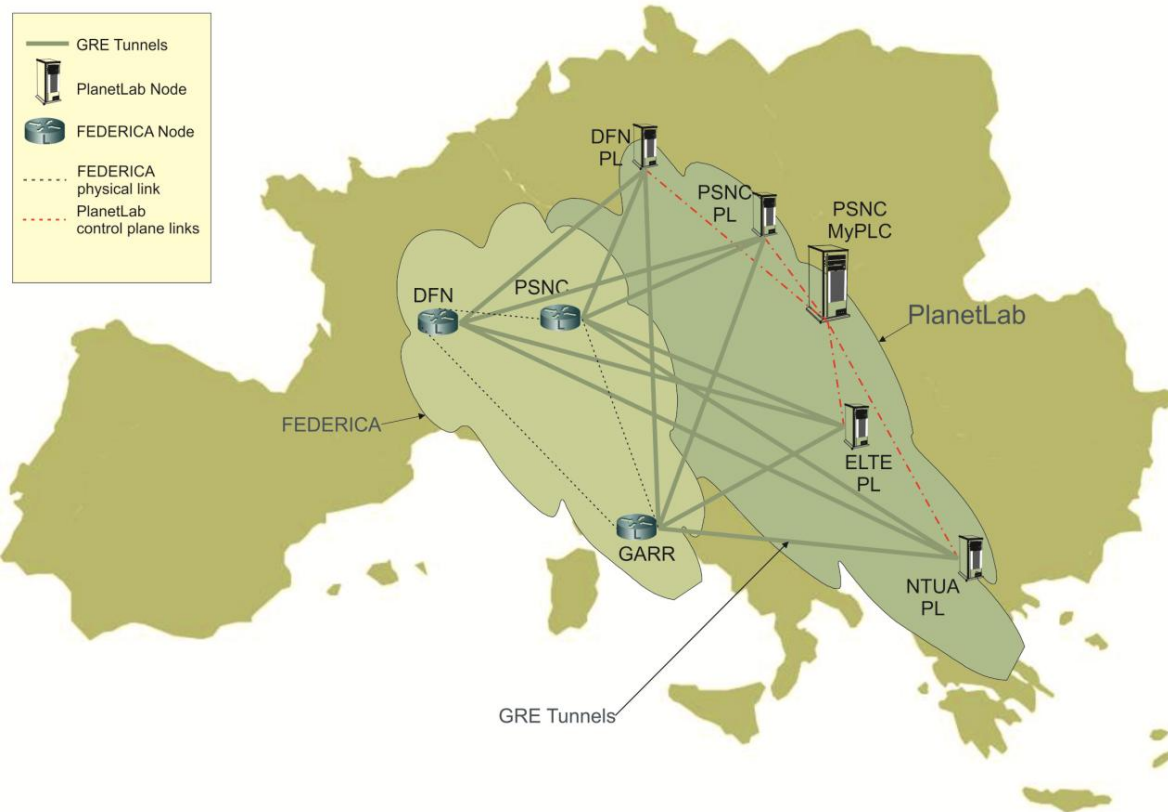**Peter Kaufmann, DFN-Verein**

Outline

- Introduction

- Project NOVI

- Network measurements with HADES

- Comparison of measurements
  - over physical substrate
  - over virtual slice environment
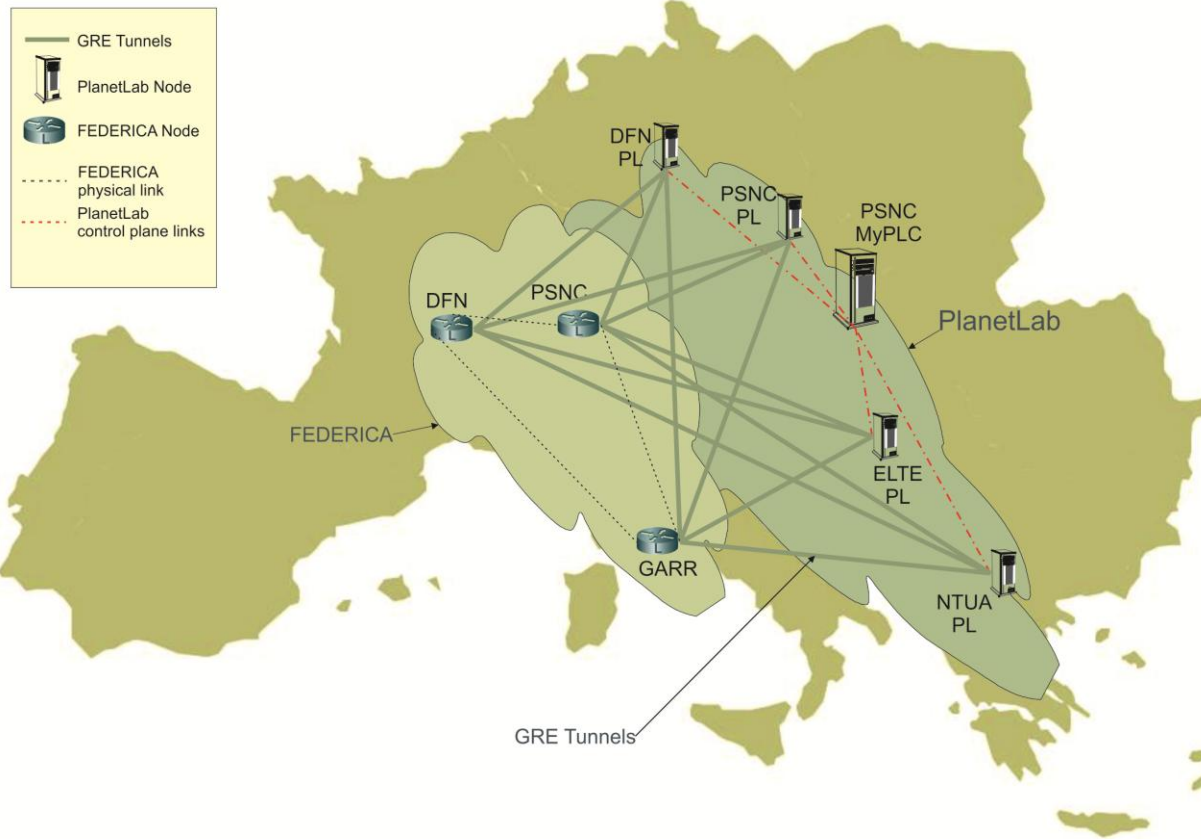
- Future Work

- Contact

Introduction

- Work performed for project NOVI

- **NOVI: N**etworking innovations **O**ver **V**irtualized **I**nfrastructures

- Project just ended

- http://www.fp7-novi.eu/

GRE Tunnels
PlanetLab Node
FEDERICA Node
FEDERICA physical link
PlanetLab control plane links

DFN PL
PSNC PL
PSNC MyPLC
PlanetLab
DFN
PSNC
FEDERICA
ELTE PL
GARR
NTUA PL
GRE Tunnels

Future Internet Platform NOVI

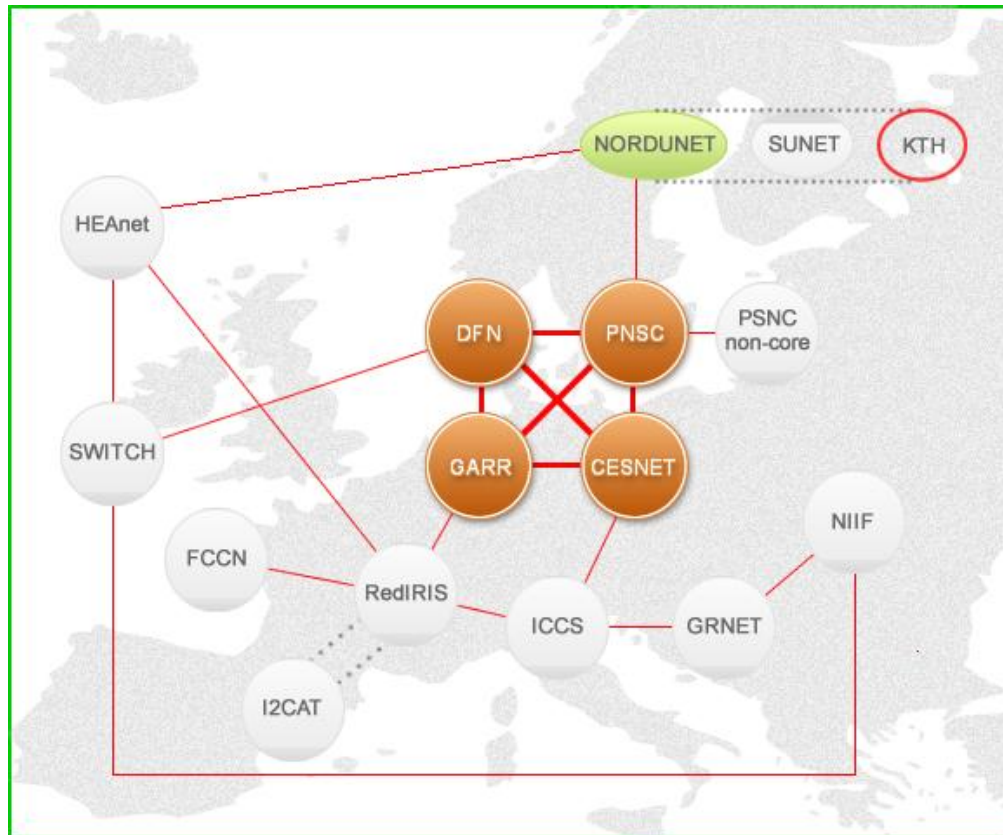* Uses resources from FEDERICA and PlanetLab

FEDERICA

Federated E-infrastructure Dedicated to European Researchers Innovating in Computing network Architectures

- core nodes in FEDERICA are Juniper programmable Logical Routers (MX-480) connected via SDH/SONET 1 Gpbs circuits

- infrastructure of virtual machines (VMs) and logical routers interconnected via dedicated layer-2 links over NRENs and GÉANT networking facilities.

- provisioning of virtual slices for network experiments that would conflict with production traffic

- http://www.fp7-federica.eu/

Federated Infrastructure

- Virtual slice provisioning over federated substrate
- Proof of concept with integrated prototype
- NOVI uses resources from
  - FEDERICA and
  - private PlanetLab instance
    - resources connected over the public Internet
    - http://www.planet-lab.org/
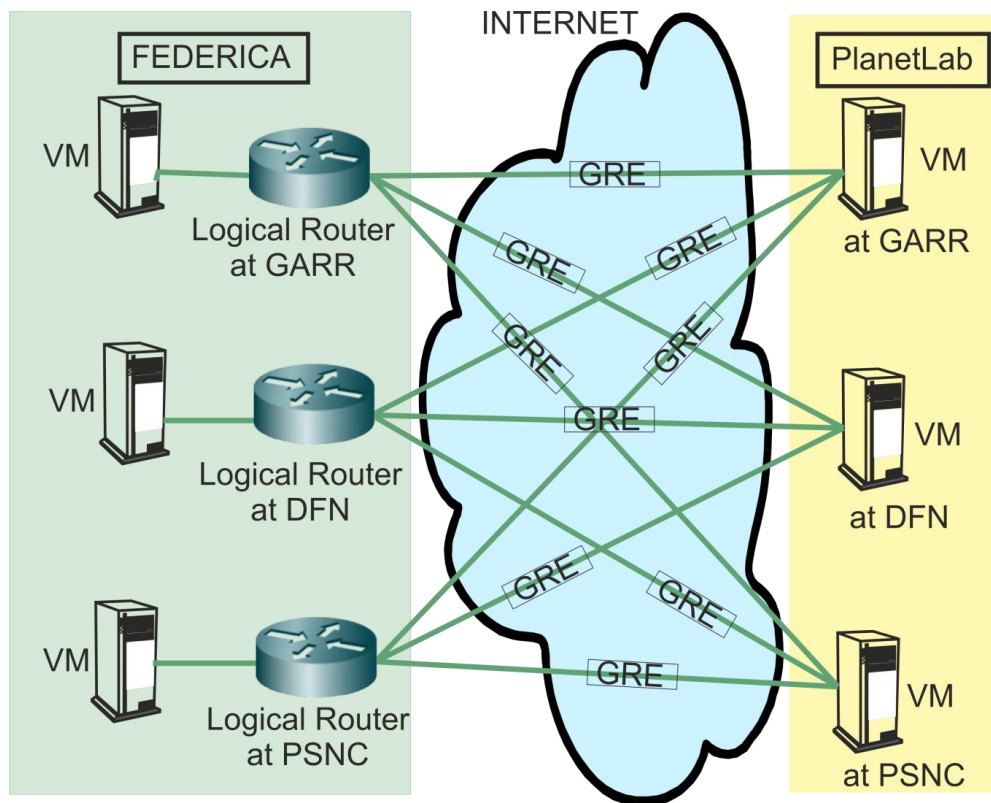 - as typical architectural representatives of a Future Internet platform

Example of virtual slice

- Virtual slice with 6 nodes

- – 3 FEDERICA based VMs
- – 3 VMs from PlanetLab
- – Connected via GRE tunnels (GRE: Generic Route Encapsulation; Tunneling protocol for encapsulating a variety of network layer protocols into virtual point-to-point links)

NOVI investigated

- How to federate different kinds of resources in virtualized e-Infrastructures

- How to formally describe virtualized network and cloud objects in a complex environment

- How to build slices of virtualized infrastructure at the data, control, monitoring and provisioning planes

- How to describe their relationships and technical attributes

- How to (co-) allocate resources with QoS attributes and how to set up the monitoring system to allow for accountable, predictable Future Internet services
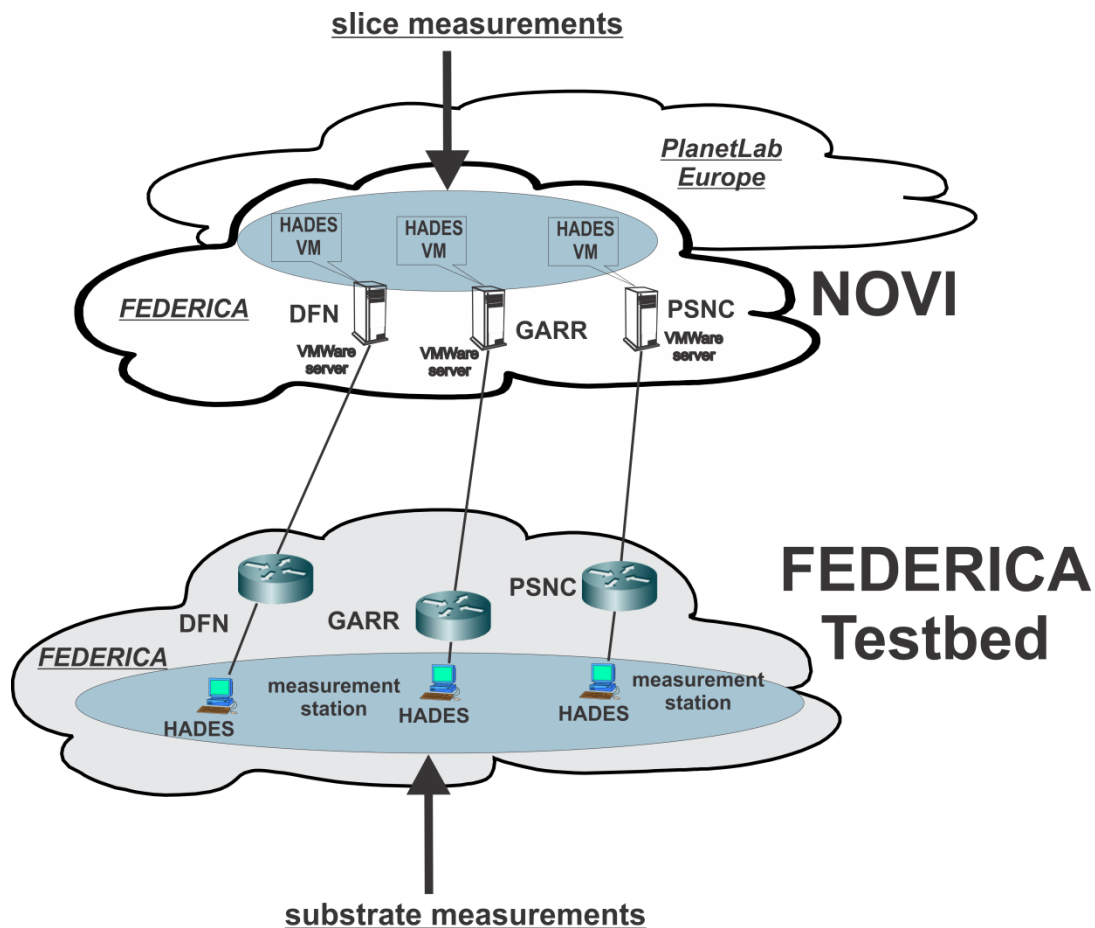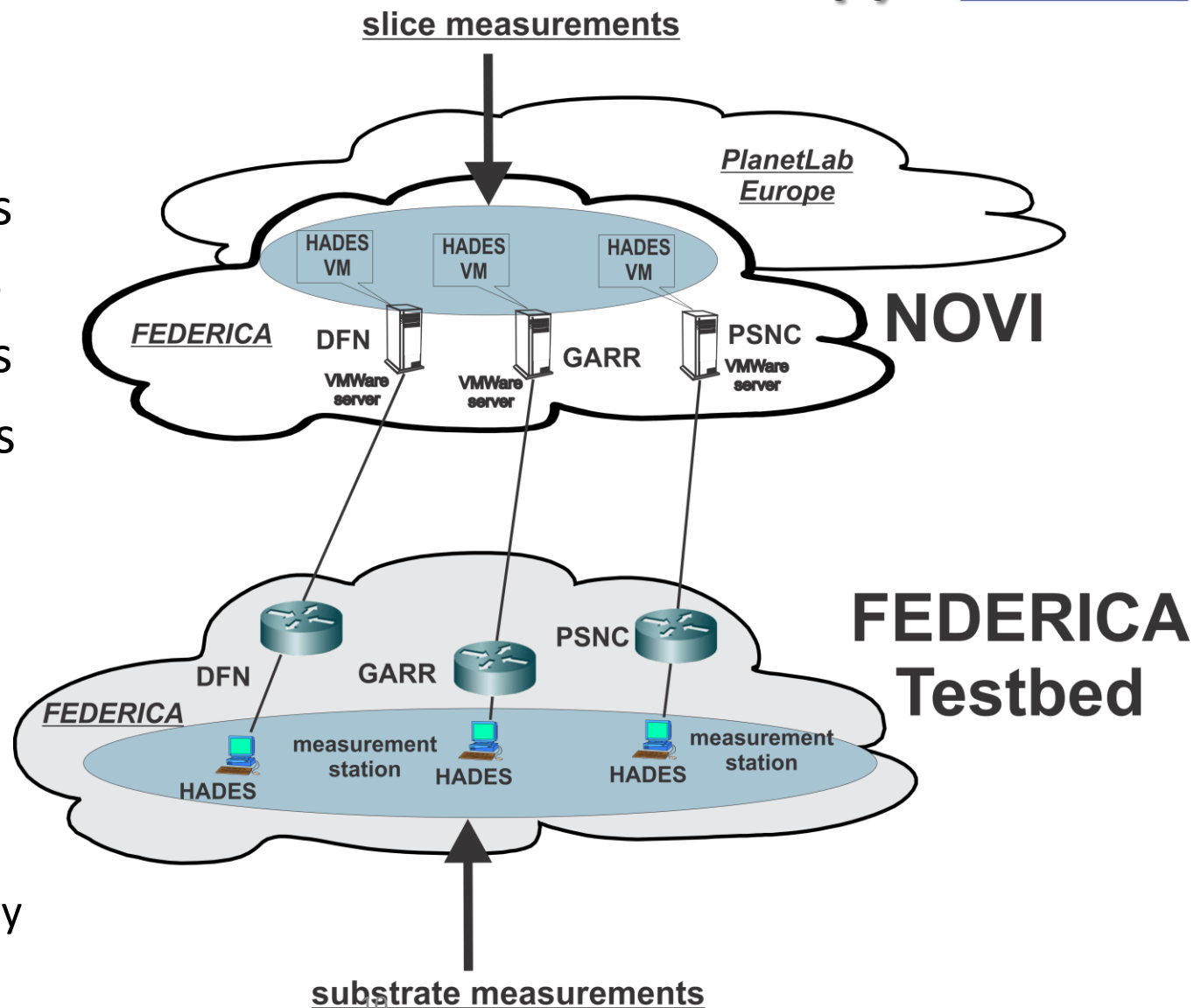
Focus on network measurements

- to get experience with network measurements in a virtual environment

- to investigate how much virtualization actually impacts network IP performance metrics

slice measurements

PlanetLab Europe

HADES VM   HADES VM   HADES VM

FEDERICA   DFN   GARR   PSNC

VMWare server   VMWare server   VMWare server

NOVI

FEDERICA

DFN   GARR   PSNC

FEDERICA

measurement station   measurement station

HADES   HADES   HADES

FEDERICA Testbed

substrate measurements

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DFN Deutsches Forschungsnetz

Comparison of measurements (I)

- **substrate** measurements

- as well as **slice** measurements

- Measurements collected at very same locations at nodes
  - GARR, Italy
 - PSNC, Poland
  - DFN, Germany

slice measurements

PlanetLab Europe

FEDERICA   DFN   HADES VM   HADES VM   HADES VM   PSNC   NOVI

GARR

VMWare server   VMWare server   VMWare server

FEDERICA Testbed

DFN   GARR   PSNC

FEDERICA   measurement station   measurement station

HADES   HADES   HADES

substrate measurements

Comparison of measurements (II)

- **substrate** measurements with dedicated HADES (HADES Active Delay Evaluation System) hardware measurement stations directly connected to Juniper MX-480 routers

- **slice** measurements with HADES software installed on VMs configured on VMWare servers connected to the Juniper routers
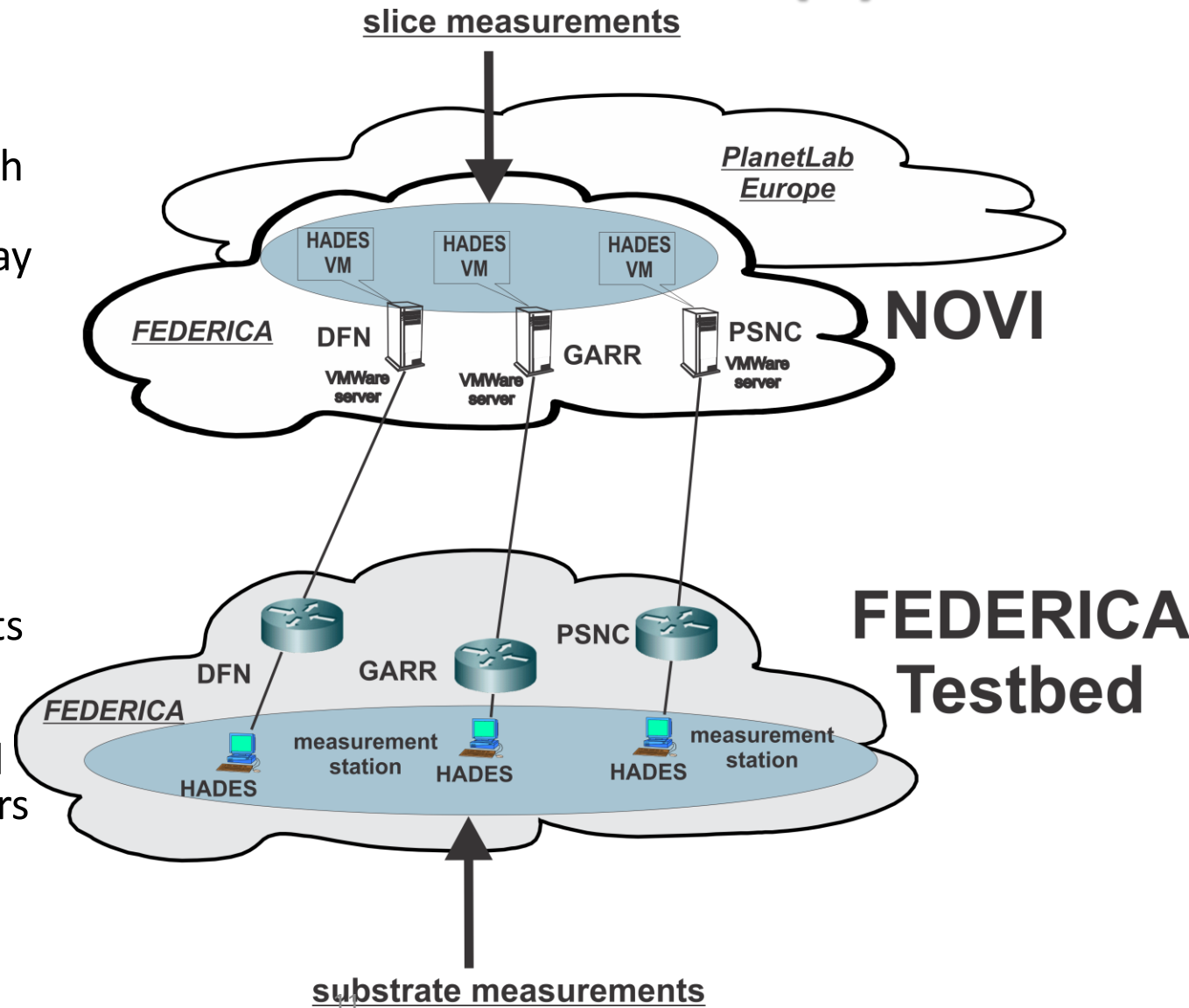
HADES Active Delay Evaluation System

- Developed at the University of Erlangen-Nuremberg for continuous network monitoring

- Performance measurements (IPPM performance metrics OWD, OWDV, packet loss)

- HADES measurements currently over
  - German Research Network X-WiN
  - FEDERICA
  - GÉANT
  - LHCOPN (Large Hadron Collider Optical Private Network)
  - MDM (perfSONAR multi-domain monitoring) networks

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Worldwide HADES Measurements

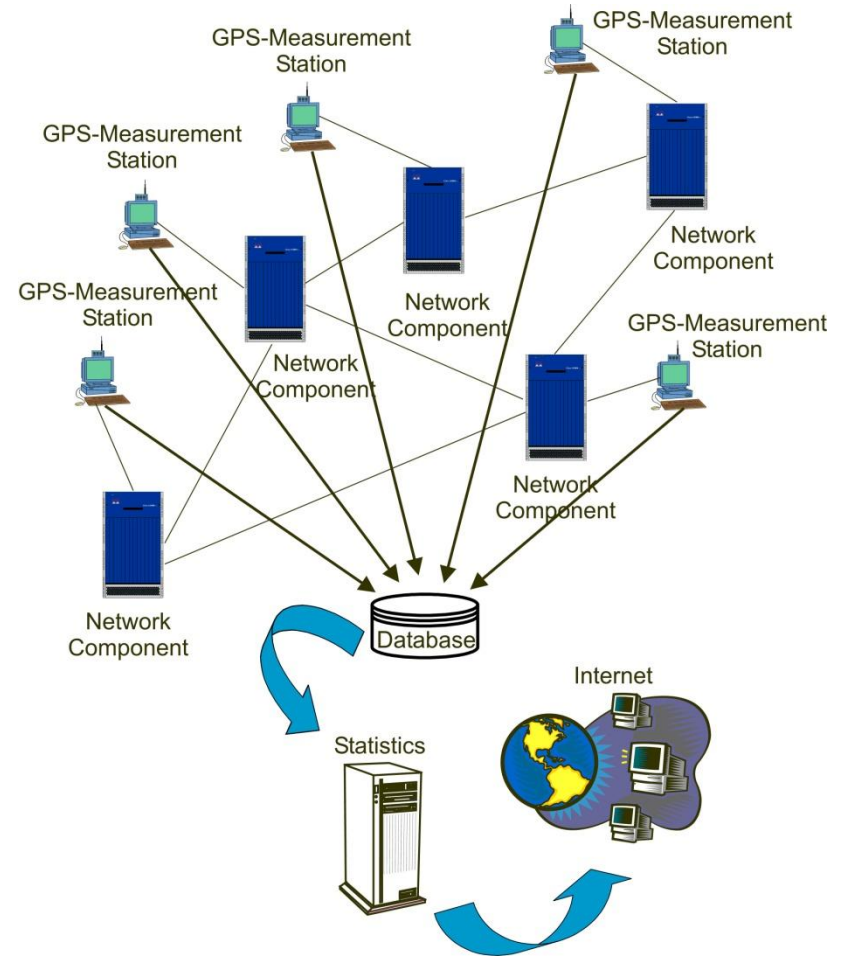| In Project	Number of Locations	Monitored Links
X-WiN	57	3500
GEANT	36	1200
MDM	23	500
LHCOPN	10	90
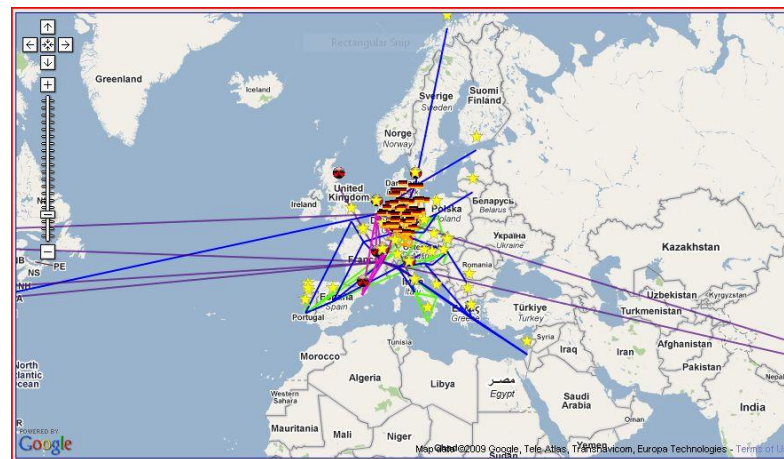
HADES

- Active measurement process

- GPS-based measurement stations (Meinberg GPS170PCI slot card connected to a GPS antenna)

- Measurements 24 hrs/day

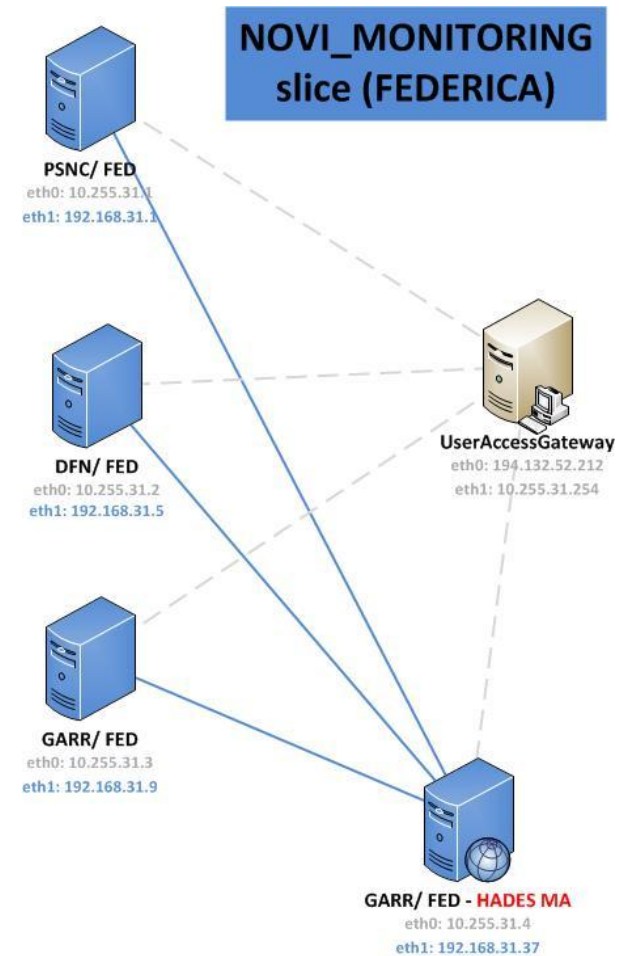- Measurements collected in HADES measurement archive (HADES-MA)

Active Measurement Process (I)

- Generation of groups of 9 UDP packets of length 25 Bytes every 60 seconds

- For each 24 hour period
  - 12960 packets were sent
  - in 1440 measurement intervals

- Three full consecutive days were used for investigation

NOVI_MONITORING slice (FEDERICA)

PSNC/ FED
eth0: 10.255.31.1
eth1: 192.168.31.1

DFN/ FED
eth0: 10.255.31.2
eth1: 192.168.31.5

GARR/ FED
eth0: 10.255.31.3
eth1: 192.168.31.9

UserAccessGateway
eth0: 194.132.52.212
eth1: 10.255.31.254

GARR/ FED - HADES MA
eth0: 10.255.31.4
eth1: 192.168.31.37

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DFN
Deutsches
Forschungsnetz

Active Measurement Process (II)

- Packets were evenly spaced over each measurement interval of 60 seconds to avoid additional waiting times at the network interface card

- Every packet carried
  - Sequence number (to determine packet loss)
  - Time stamp

- Receiver marked time of arrival

- One group = 9 packets (median, maximum, minimum delays)

Measurements in parallel (I)

- over physical infrastructure
  - GPS signal is used to synchronize the local quartz clock on the Meinberg card and the measurement station in return uses this signal for synchronization of its own host clock

- over virtual slice environment
  - local clock provided by the operating system of the HADES measurement archive (MA) at GARR selected as time reference
  - This time reference distributed to HADES software clients via NTP
  - VMs truly isolated within the NOVI slice (therefore no outside clock reference possible)
  - time stamps were only used within their local reference systems (substrate or virtual)
  - no absolute delay values, only variation of delay was considered
  - different reference clocks, but each system consistent and steady in itself
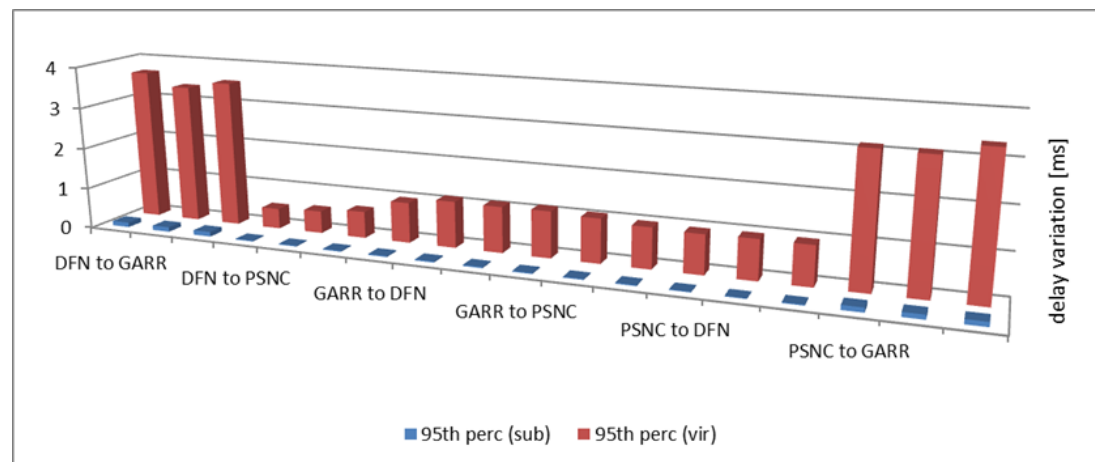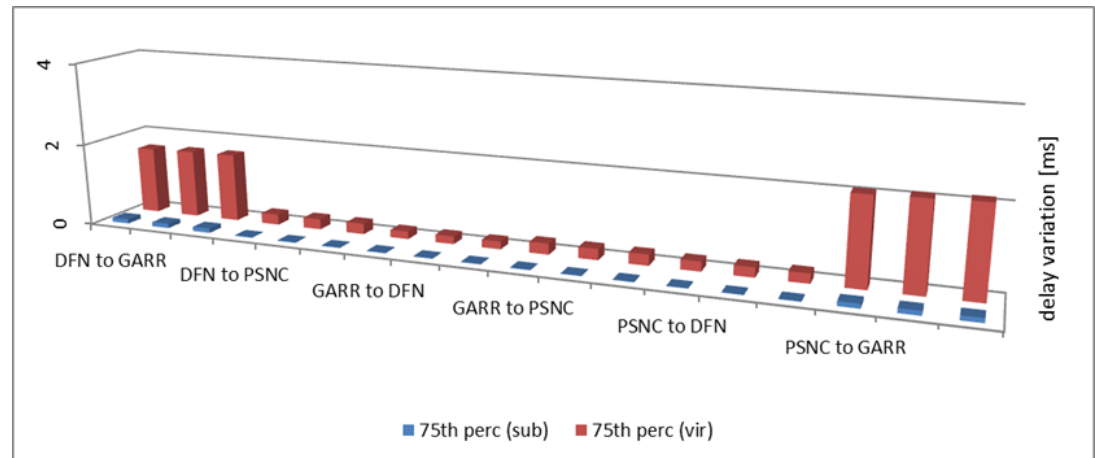
Measurements in parallel (II)

- For both physical and virtual environments, network measurements over the following links were compared:
    - DFN-GARR
    - DFN-PSNC
    - GARR-DFN
    - GARR-PSNC
    - PSNC-DFN and
    - PSNC-GARR
- one-way delay variation was investigated
- 75th, 90th, 95th and 97th percentiles of delay variation for each measured link were obtained

Measurements in parallel (III)

- comparison of delay variation
  - Substrate (blue)
  - Slice (red)
- generally higher variation in slice
- highest values in slice over links with destination GARR

Measurements in parallel (IV)

- G3 monitoring system [by CESNET] in place over FEDERICA was also used to investigate
  - average CPU usage
  - number of running VMs on each VMWare server

  during measurement period

- similar **number of VMs** was running on each VMWare server at the nodes:
  - S1 VMWare server at PSNC had 14 VM instances
  - S1 VMWare server at GARR reported 13 VMs
 - S1 VMWare server at DFN listed 12 VMs as running

Measurements in parallel (IV)

- **average CPU usage**:
  - average CPU usage for DFN was listed as 7%
  - PSNC showed an average CPU usage of about 5%
  - GARR had highest average CPU usage of about 90%
- high average CPU usage at GARR led to a heavy impact on delay variation in slice
- high load prevented arriving packets from immediately being served, i.e. the receiving time stamps could only be attributed to the packets at a much later time
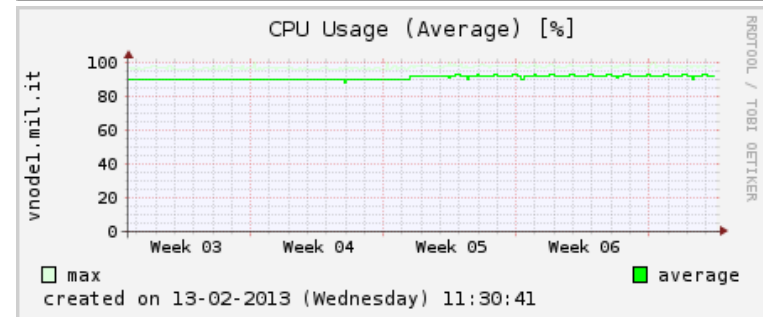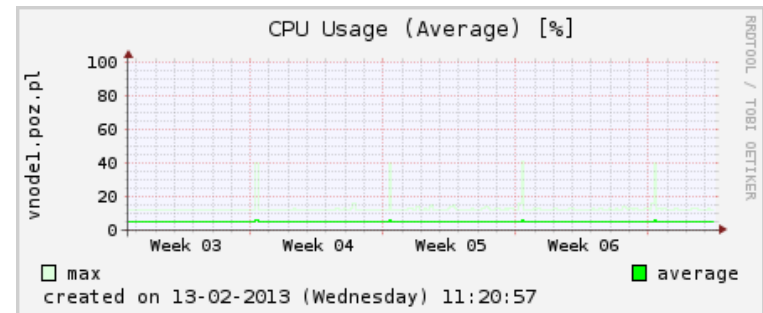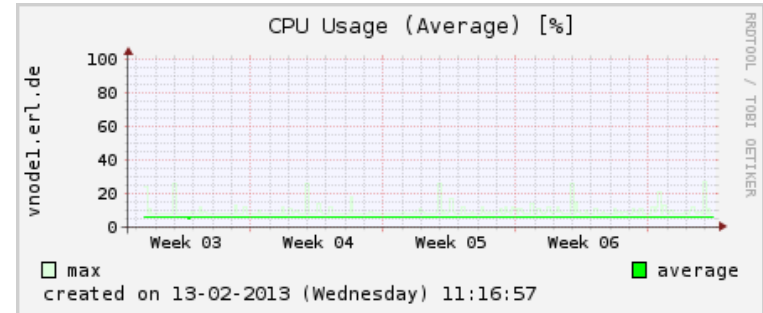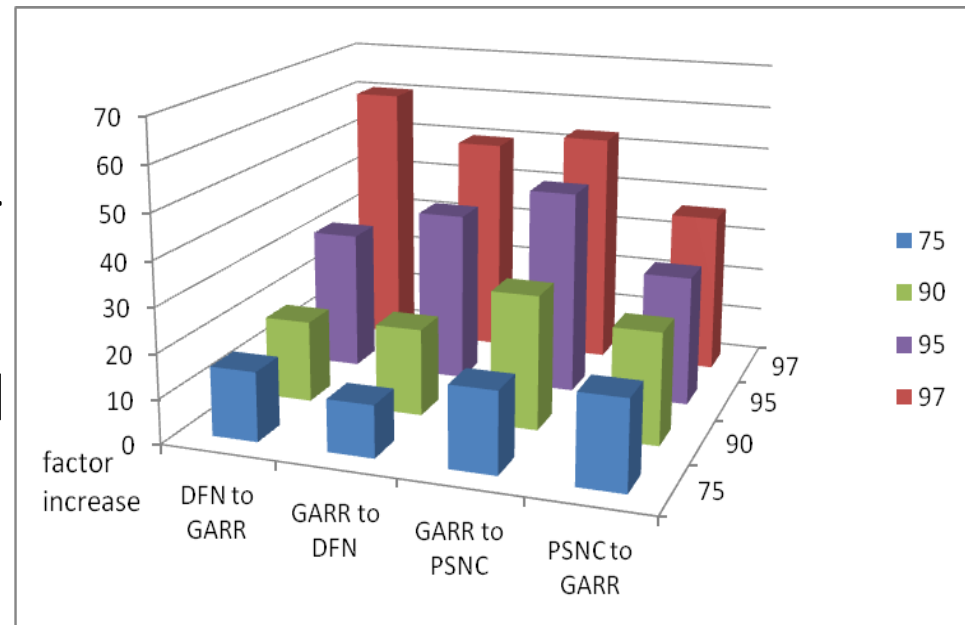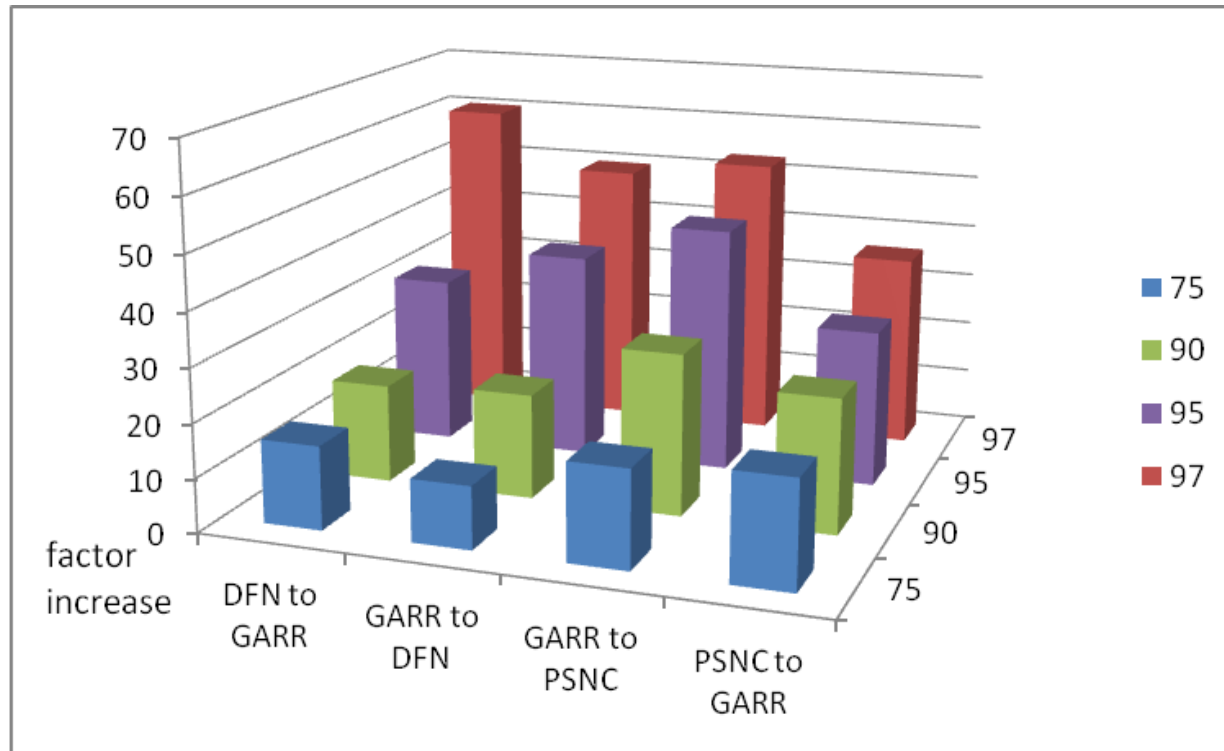
Measurements in parallel (V)

- Investigation of factor increase of delay variation (substrate vs. slice)

- median values of the one-way delay variation samples were averaged over measurement period

- assessment by how much of a factor the delay variation had actually increased in the virtual slice

Measurements in parallel (VI)

- average median one-way delay variation in the slice increased by at least a factor > 10 (75th percentile)
- increased by a factor of almost 20 (90th percentile)

Future Work

- Can other parameters aside from CPU load also have an impact on delay variations?

- focus on applications and how their Quality of Experience (QoE) will be impacted by the virtualization in Future Internet platforms

- Questions?

Contact

- For questions please contact:

    - Susanne.Naegele-Jackson@fau.de
    - Kaufmann@dfn.de

- More information (NOVI):

    - http://www.fp7-novi.eu/