3D Chip-Stacks

TSVs
inductive/capacitive
optical

© TU Dresden

© Samsung

© Samsung
Highly Adaptive Energy-Efficient Computing

High-Rate Inter-Chip Communications

Optical Interconnect
- adaptive analog/digital circuits for e/o transceiver
- embedded polymer waveguide
- packaging technologies (e.g. 3D stacking of Si/III-V hybrids)
- 90° coupling of laser

Radio Interconnect
- on-interposer/on-package antenna arrays
- analog/digital beam steering and interference minimization
- 100Gb/s
- 25 GHz channel @ 220Hz carrier
- 3D routing & flow management
The Outlook: The **HAEC** Box in 2020+

Assume
- 128K processors per chip
- 128x chips stacked in 3D
- 4x4 chip-stacks on board
- 4x boards in a box

in 10x10x10 cm³ (1 liter)

8192 chips ➔ 10⁹ processors!

➔ 10⁵x performance of today!
The Tactile Internet
2005/4/4 – Via Della Conciliazione

Source: http://www.spiegel.de/panorama/bild-889031-473266.html
2013/3/12 – Via Della Conciliazione

Ad-Hoc Mobile
“Free-Viewpoint Video”

Source: http://www.spiegel.de/panorama/bild-889031-473242.html
Physiology and Psychology

1 sec

100ms

10ms

1ms
Remote Heli

i-Flight

http://ds_product_photos.s3.amazonaws.com/large/9756.jpg
Gaming…

http://popular-pics.com/Cool_World_Record_LAN_Event_Computer_Pictures
http://gametaffy.com/imho-the-lan-party
Professional Audio

Platooning 2.0

1ms examples of today’s cars: ESC/ESP, ABS

Tomorrow: platooned ESP & ABS
Traffic Control
Manufacturing

http://www.augsburg.de/fileadmin/www/dat/fotoservice/wirtschaft/kuka/kuka_1.jpg
1ms Impact

Latency Goals:

\[ \Sigma = 0.3 \text{ ms} \]

\[ \Sigma = 0.2 \text{ ms} \]

\[ \Sigma = 0.5 \text{ ms} \]
Additional (non-functional) Requirements

- Accountability & Archiving
- Failure Resilience
- Authorization
- Attacker Resilience
- Eavesdropping Security

carrier grade e.g. (3%)\(^5\)

secure
fast actuators sensors & transceivers

Coordinators: Frank Ellinger & Gerhard Fettweis, TU Dresden
Starting 2014, approx. €100M

fast value chain
sales & service systems, networks, software circuits components semi-conductors

fast network of states
Berlin Brandenburg Mecklenburg Vorpommern Saxony-Anhalt Saxony Thuringia & Baden-Württ. Lower Saxony Bavaria

ETSI Future Mobile Summit
G Fettweis 21 November 2013
Cellular Roadmap of USP

- **2G – 1992**
  - Voice Messages

- **3G – 2002**
  - Data
  - Positioning

- **4G – today**
  - Video everything
  - 3D Graphics

- **5G – 2022**
  - Tactile Internet
  - M2M
  - Tb/s WiFi
Communications ➔ +Monitoring ➔ +Control

Speed: >10 Gb/s
COMMUNICATIONS

MONITORING
>10 years, 10b/s (1Ah)

CONTROL
Response: 1 ms
Thanks al lot to Vodafone for 19 years of continued support!

www.vodafone-chair.org

Tactile Internet http://www.youtube.com/watch?v=_VXEjPzQgpk
CFAED cfaed.tu-dresden.de
HAEC www.tu-dresden.de/sfb912
3DCSI www.twinlab3d.org
fast www.fast-zwanzig20.org