Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

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Abstract: This documents follows the discussions at the previous IEEE 802 plenary's on spinning off a Study Group on THz Communications. To start this process a proposal is made to focus first on the application of THz Communications at wireless data centers. The documents concludes with a proposal for a roadmap on creating a study group.

Purpose: Information of IG THz

Launching a Study Group on THz Communications

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Outline

- Motivation for this Presentation
- Brief review on rationale and state of the art in THz Communications
- Application of THz Communications to Wireless Data Centers
- Next Steps / Roadmap to create a SG

Motivation for this Presentation

Motivation for this Presentation

- State of discussion at previous sessions of IG THz:
  - Technology has made significant progress
  - Discussion on various applications and usage models
  - The idea to spin-off a SG on THz Communcations has been discussed intensively
- Situation on standard development THz Communications may be a bit different from other standards:
  - For the time being development of THz communcations is technology driven and not pushed from market requirements
  - This is a technology getting more and more mature, but what will be the appropriate application to start with?

„Boundary Conditions“ for Starting a Study Group (1/2)

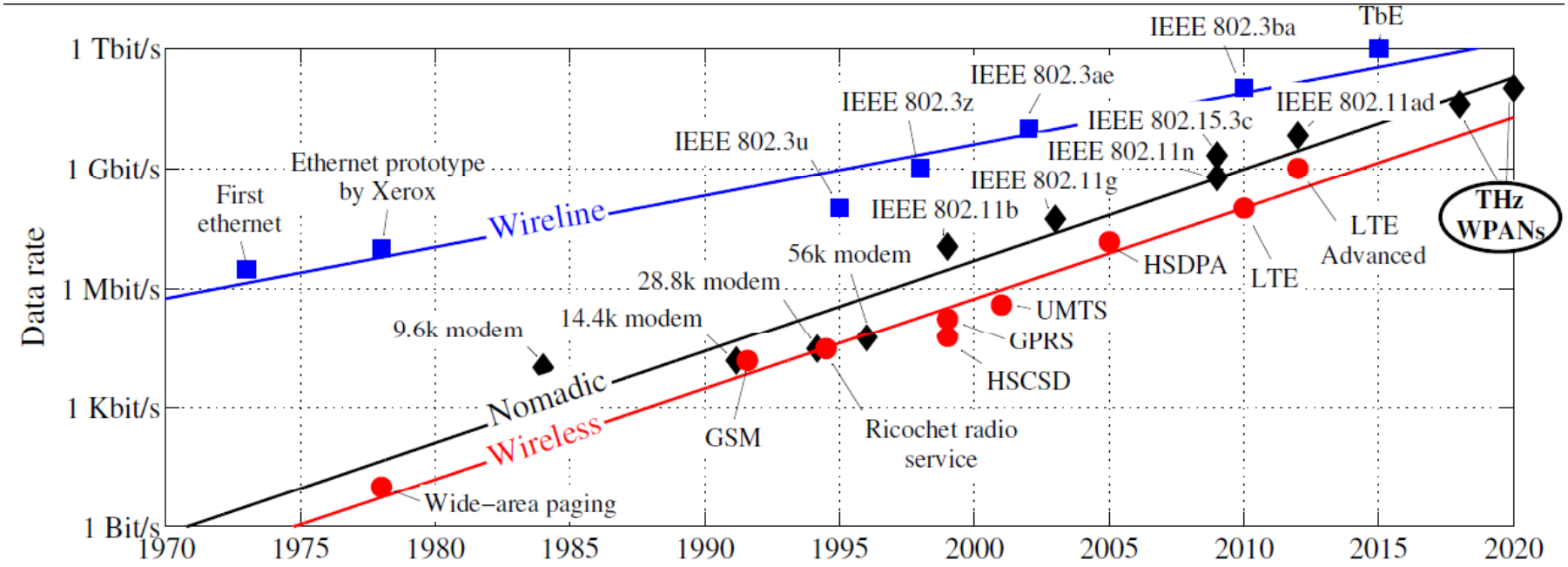
- The only task for a SG is to
  - Write a PAR
  - Write a document on 5C
- We should start a SG only when we have confidence that we are able to successfully produce a PAR and 5C document
- Therefore the following pre-requisits should be fulfilled
  - The selected application has to attract interest in industry. This happens best, if this new technology helps to solve a real-world problem
  - Technology should be mature enough to master the complextity imposed by the operational conditions of a specific application

„Boundary Conditions“ for Starting a Study Group (2/2)

- Starting a SG on a specific application does not mean the end of the IG THz
  - The IG THz will continue its work creating opportunities to spin-off in the future. New SGs on other applications and operational environments may follow.

Brief review on rationale and state of the art in THz Communcations

Evolution of Data Rates in Wireless



- 60 GHz Standards already completed enable data rates of 6-7 Gbit/s
- Assuming the development observed in the past years extrapolate into the future we will see wireless 100 Gbit/s around the 2020

Source: based on IEEE 802.15-12-0320-02-0000-Tutorial_IGthz

Principle Possibilities to achieve Wireless 10x Gbps

- Further development of 60 GHz systems by enhancing spectral efficiencies (15 bps/Hz to achieve 100 Gbps with 7 GHz bandwidth)
- Use FSO or IR solutions (eye safety, modulation and cost issues at least with some applications ?)
- Use more spectrum and apply moderate spectral efficiencies => enough frequency spectrum available beyond 300 GHz only

State of the art in Technology for THz Communications (1/2)

- > 20 Gbps have been demonstrated by various groups
  - Song et. al. [1] demonstrated 24 Gbit/s at 300 GHz using an electro-optical transmitter and an electronic receiver.
  - Kallfass, Antes et al [2,3] demonstrated 25 Gbps at 220 GHz over a distance of 10 m using InP/GaAs based MMIC technology

- CMOS solutions at THz frequencies are challenging
  - However, first approaches are promising and show a clear potential (see e. g. 15-12-0621-00-0thz_THz_CMOS)

State of the art in Technology for THz Communications (2/2)

- Current demonstrations are focussing on point-to-point links only.
- Many applications require automatic beamsteering capabilities.
- Beamsteering has not been demonstrated yet (first projects targeting this may start soon)
- First systems to be standardised should not require full beamsteering capabilities.

Mass Market vs. Non-Mass Market Applications

- Yet the more expensive compound semiconductor technology (InP,GaN,GaAs) seems to be mature enough.
  - Expensive technologies might be feasible for non-mass-market applications only
  - Willingness to pay for performance is necessary
- Cheaper CMOS technology can provide solutions in the future as well.
  - This will pave the way for mass-market applications targeting consumer electronics.
- From a technology point of view applications not targeting the consumer market seem to be more appropriate to start with.

Regulatory Situation (1/3)

ITU Radio Regulations Footnote 5.565:

The frequency band 275-1000 GHz may be used by administrations for experimentation with, and development of, various active and passive services.

- Radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, [...]
- Earth exploration-satellite service and space research service 275-277 GHz, 294-306 GHz, 316-334 GHz, [...]

Administrations are urged to take all practicable steps to protect these passive services from harmful interference.

→ Two options for THz communications:

1. Transmission in remaining free parts of the THz spectrum
2. Coexistent spectrum usage with radio astronomy/earth exploration

Source: based on IEEE 802.15-12-0320-02-0000-Tutorial_IGthz

Regulatory Situation (2/3)

1. Transmission in remaining bands only
   - Very small bandwidths
   - Distributed over entire THz range

→ Not feasible for data rates >> 10 Gbit/s

2. Coexistent spectrum usage
   - Potential interference of active THz systems with
     - radio astronomy
     - spaceborne THz sensors

→ Interference investigations inevitable for standardization to comply with the ITU Radio Regulations

Remaining Frequency Bands	Total available Bandwidth
286-294 GHz	8 GHz
307-313 GHz	6 GHz
356-361 GHz	5 GHz
366-369 GHz	3 GHz
392-397 GHz	5 GHz
399-409 GHz	10 GHz
411-416 GHz	5 GHz
434-439 GHz	5 GHz
467-477 GHz	10 GHz
502-523 GHz	21 GHz
527-538 GHz	11 GHz
581-611 GHz	30 GHz

Source: IEEE 802.15-12-0320-02-0000-Tutorial_IGthz

Regulatory Situation (3/3)

- Using large bandwidths (in the order of 20-50 GHz) for THz Communications requires the sharing of spectrum with passive services.
- Developing appropriate measures to avoid interference to passive services is obligatory.
- Applications in indoor and shielded environments inherently avoid interference.

Possible Usage Models and Applicatons for THz Communications

- „Mobile“ THz WLAN/WPANs with full active beamsteering and phase control
  - In-room multi user WLANS
  - Pedestrian plazas in buildings
  - Broadband stadium access
  - Automotive/Rail/Aircraft/ Applications
- „Fixed“ THz WLANS/WPANS with limited beamsteering
  - Multi-processor gaming stations
  - 4kx4k TV/in-room entertainment links
  - Business kiosk video download
  - Backhauling for cellular networks
  - Server farms (wireless data centers)

Source: based on 15-12-0652-01-0thz-discussion-document

How about Developing a THz Standard for Wireless Data Centers?

- Wireless data centers
  - are non-mass market applications, where compound semiconductor devices may be used
  - do require limited beamfoming capabilities only (at the time of system reconfiguration)
  - are operated in shielded rooms and make it easy to share spectrum with passive services
  - Customers have a willingness to pay for performance and to simplify their network complexity
- But does THz Communications help to solve a real-world problems there?

Application of THz Communications to Wireless Data Centers

Today‘s situation at data centers

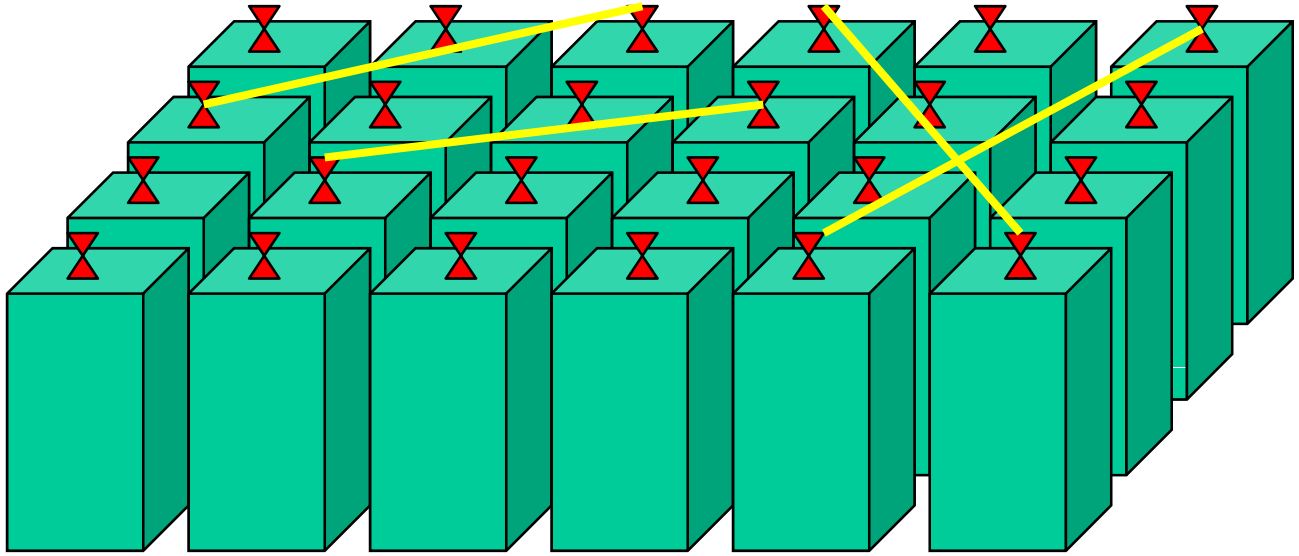
- Due to rapid data explosion more data centers consisting of more data centers are required
- Data intensive systems may have hundreds of thousands of computers yielding enourmous requirements for aggregate network bandwidth
  - In 2009 Google had 10 milion servers
  - Microsoft had 50000+ servers in their data centers
- Architecture design of the data center is critical to the total performance
  - Requirements for easy reconfiguration
- Cabling complexity
  - Intensive cabling introduces problems like connecting efforts, maintenance and cooling

Source: [4]

Adding wireless connections to wireless data centers

- With pure wire solutions dynamic reconfiguration of data centers is not easy
- Wireless connections in the data center may help both in achieving easier dynamic reconfigurability and reduce cabling.
- [4] propses a hybrid solution consisting of both wired and wireless connections
- In [5] a wireless data center based on IEEE 802.15.3c is proposed.
- [6] mentions explictly THz frequencies to increase bandwidth and proposes out-of-band lower frequency channels based on IEEE 802.11s

Example of a Wireless Data Center



Some properties of wireless connections in data centers

- Beamsteering and high gain antennas enhance spectral efficiency and reduce collision probabality.
- Steered-beem control is optimized during system initialisation and stored until next system reconfiguration
- Due to lower transmission range and high penetration losses, high frequencies can enhance security
- In [7] 3D beamsteering using the ceiling as a passive relay is proposed to overcome potential shadowing by racks

Source: [6]

Implications on other Applications for THz Comunications

- Standardization of a THz systems for wireless data centers can pave the way for other applications
- Availability of cheaper CMOS technolgy will enable the adoption of the standard to nomadic mass-market applications, e. g. gaming

Next Steps / Roadmap to create a SG

Next Steps towards a SG on THz Communications

- More participation from industry on this topic is required
- Possible measures to attract more industrial participation
  - Preparing a Call for Interest on „THz Communications for Wireless Data Centers“
  - Explore the possibilities the IEEE Industry Connection offers
  - Explore possibilities to engage IWPC
- Preparing a White Paper
- If enough interest is created, the IG THz should consider to make a motion at the July 2013 Plenary to spin-off a Study Group on „THz Communications for Wireless Data Centers“

List of References

[1] H. J. Song et. al., „24 Gbit/s data transmission in 300 GHz band for future terahertz communications“, Electronic Letters, 1th July 2012, Vol. 48, No.15

[2] I. Kallfass et. al., “All Active MMIC Based Wireless Communication at 220 GHz, "IEEE Trans. on Terahertz Science and Technology, vol. 1, no. 2, pp. 477-487, Nov. 2011

[3] J. Antes et. al. ,”MMIC based wireless data transmission of a 12.5 Gbit/s signal using a 220 GHz carrier,"in Proc. European Microwave Integrated Circuit Conf., Manchester, pp. 238-241, 2011

[4] Kaishun Wu, „Rethinking the architecture design of data center networks”, Front. Comp. Science, Review Article, 2012 (9 pages)

[5] H. Vardhan, Wireless Data Center with Millimeter Wave Network, Proc. IEEE Goecom 2010

[6] Katayama Y, Takano K, Kohda Y, Ohba N, Nakano, “Wireless data center networking with steered-beam mmwave links”, in: Proceeding of 2011 IEEE Wireless Communications and Networking Conference. 2011, pp. 2179–2184

[7] Zhang W et. Al, „3D beamforming for wireless data centers”, in Proceedings of the 10th ACM Workshop on Hot Topics in Networks. 2011