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

Submission Title: On the Scope of IEEE 802.15 SG 100G

Date Submitted: 11 November 2013

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Abstract: This presentation gives some background information and the scope of IEEE 802.15 SG 100G.

Purpose: Information on the Scope of IEEE 801.15 SG 100G in the 802.1 / 802.15 TG10 / 802.15 SG100G Joint Session

On the Scope of the IEEE 802.15 SG 100G

Thomas Kürner

TU Braunschweig

Disclaimer: This presentations presents the view of the author and not necessarily the view of the whole Study Group

Outline

- Background in IEEE 802.15 IG THz (2008-2013)
- Working towards a Study Group targeting wireless 10x Gbps
  - Some Boundary Conditions
  - Investigating possible Applications
  - Some thoughts on Wireless Data Centers
  - Investigating on which MAC to build on
  - Some thoughts on the PHY
  - Motion to form a Study Group
- Current Status of the Study Group

Some Background – Scope of the IEEE 802.15 IG THz (2008 – 2013)

Based on the slides from our 2nd Tutorial given at IEEE 802 Plenary in July 2012

(IEEE 802.15-12-0320-01-0thz_Tutorial_Igthz)

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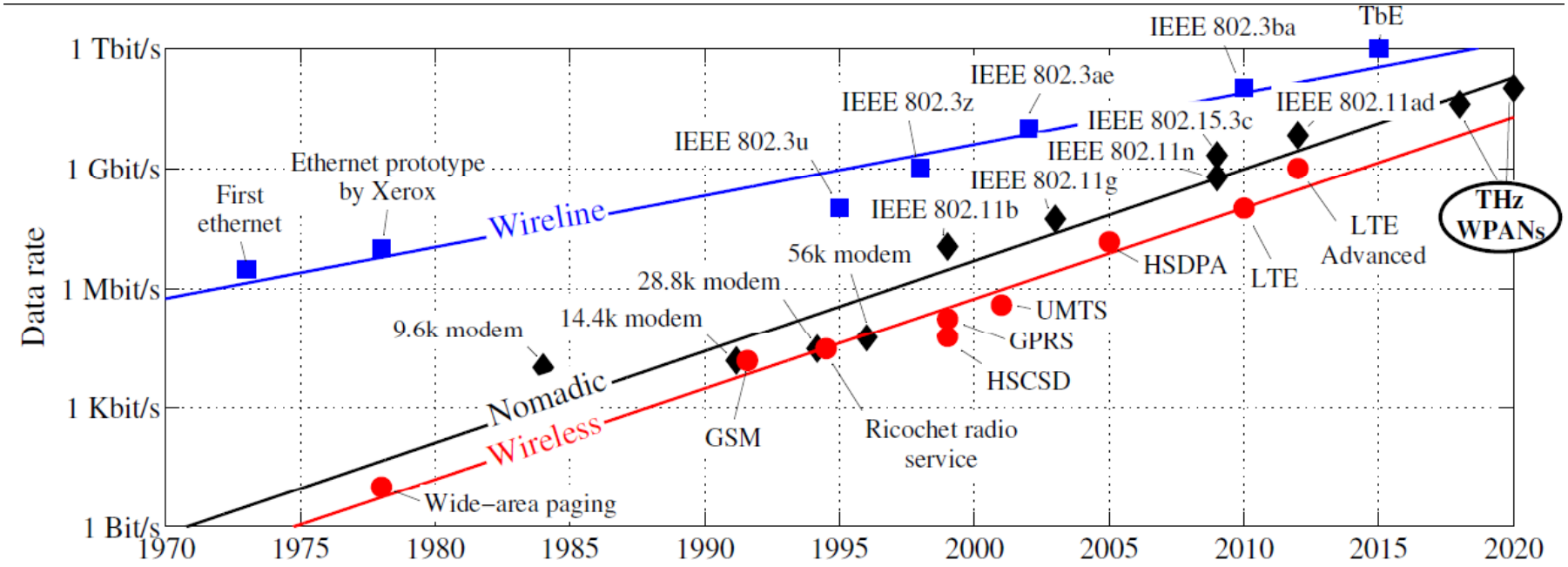
Evolution of Data Rates in Wireless



- 60 GHz Standards already completed or currently under development 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

How much data can be transferred in one second?

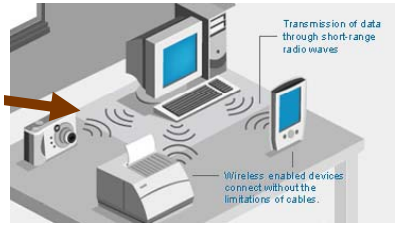
Data rate	Size	Run time of 1080p24 video(*)
10 Gbps	1.25 GByte	4 min
40 Gbps	5.0 GByte	17 min
100 Gbps	**12.5 Gbyte**	**42 min**
1 Tbps	**125 Gbyte**	**7 hours**

(*)1080p24 video are hold on BlueRay-Discs and run at up to 40-Mbps rate
(source: http://en.wikipedia.org/wiki/1080p24)

What do we need x10 Gbit/s for?

- Aim: Ultra high data rates of 100 Gbit/s and beyond over rather short distances
- Potential scenarios:

10...50 Gbit/s

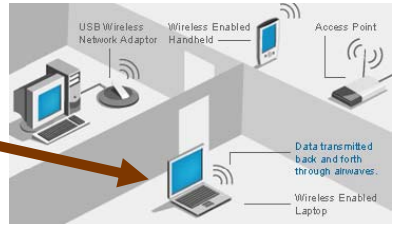


(1) WPAN

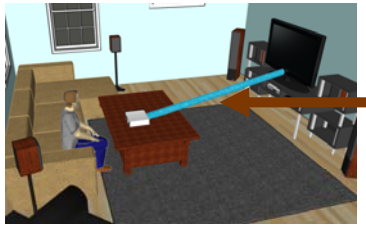
10...20 Gbit/s

(2) Kiosk downloads

10...100 Gbit/s



(3) WLAN



20...100 Gbit/s

(4) Video streaming

→ But: Why using THz communications to achieve these data rates?

Why choosing THz frequencies?

- Spectrum allocations by the ITU below 300 GHz:

http://discovermagazine.com/2007/jun/tireless-wireless/allochrt_lg.jpgIssue

→ No free spectrum available below 300 GHz to achieve such high data rates with moderate spectral efficiencies

→ No dedicated frequency allocation beyond 300 GHz (0.3 THz)

THz @ IEEE 802.15: IG THz

- Already in 2008 IEEE 802.15 has established a THz Interest Group for Wireless Systems operating at 300 GHz and beyond

- Tasks of IEEE 802.15 THz Interest Group
  - Survey of technological developments
  - Channel modeling
  - Spectrum Issues (Interference studies THz Communications -> passive services)
  - Generating a Techncial Expectations Document (TED)
  - Triggering the formation of one or more Study Groups to develop one or more standards

- Chair: Thomas Kürner (TU Braunschweig, Germany)
- Vice-Chair: David Britz (AT&T Shannon Labs, USA)
- Secretary: Katsuhiro Ajito (NTT Corp., Japan)
- Editor of TED: Rick Roberts (Intel, USA)

Challenges to be adressed to make THz communciation happen

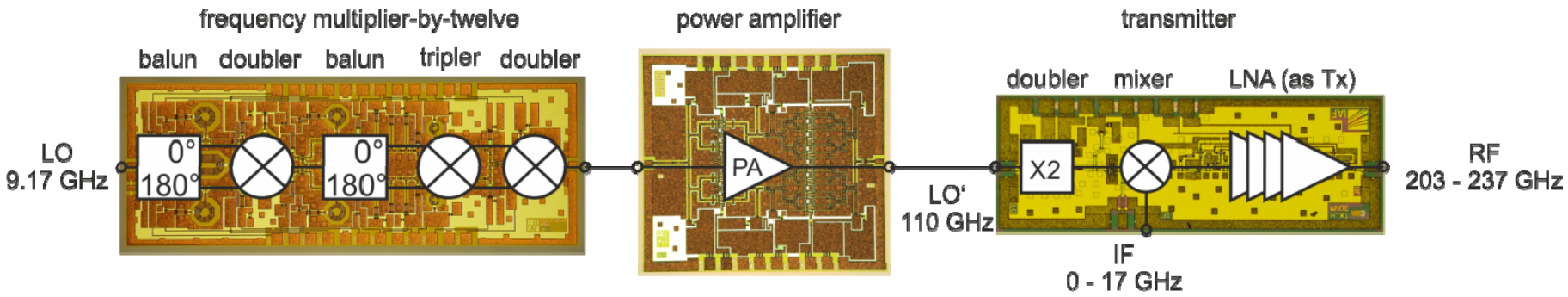
- Propagation Channel beyond 300 GHz
  - To overcome the high path loss high-gain antennas in combination with beamforming/beamsteering are required
  - @100 Gbit/s only extremely low RMS delay spread in the order of a few ns can be tolerated

    -> High-gain antennas can also help to reduce the impact of multipath propagation

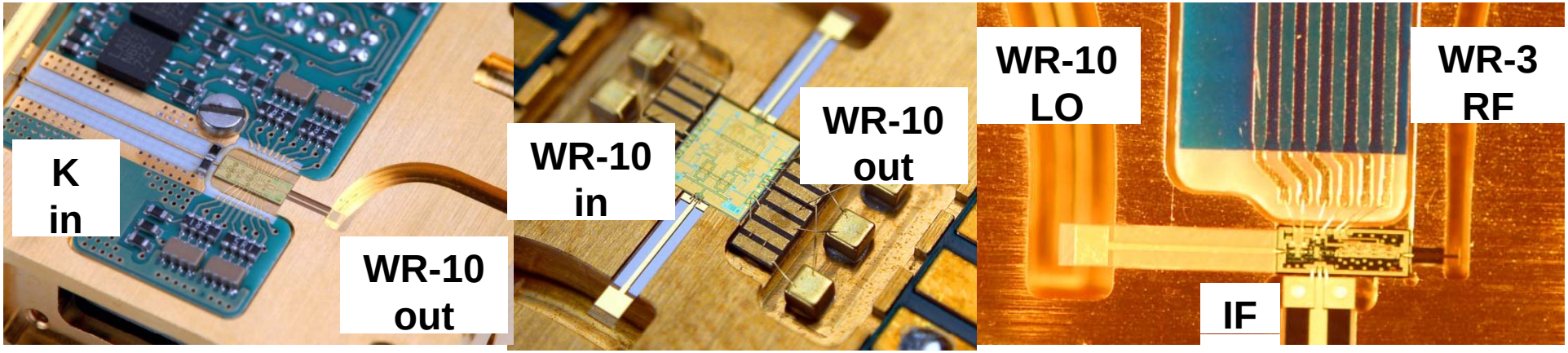
- Transmission and Networking
  - Appropriate solutions for PHY and MAC have to be defined

- Technology
  - In order to allow highy integrated transceivers technology with transit frequencies beyond 1 THz is required
  - Electro-optical or electronic generation of THz signals?

Chip Set for 220 GHz Transmission

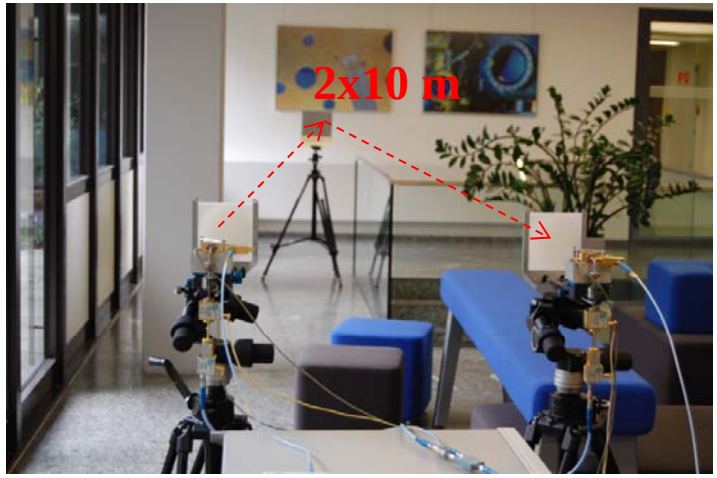


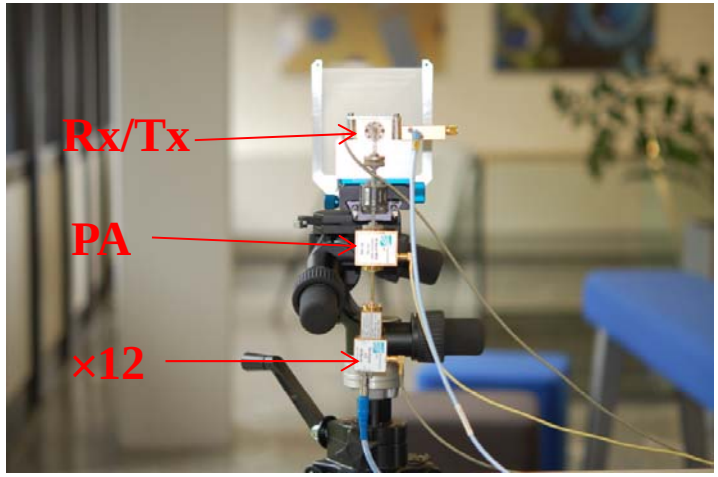
Technology: IAF 50 nm mHEMT f_T/f_{max} 515/900 GHz



220 GHz Transmission Experiments

Setup	Rate	Dist.	Quality
Coherent LO	25 Gibt/s	10 m	Q >3
	15 Gbit/s	20 m	
	Full DVB-S	20 m	n/a
	30 Gbit/s	n/a	BER < 10^{-3}
	16 Gbit/s	2 m	Q^2 > 13.9
Incoherent LO	16 APSK/ 1 GBd/s	3 m	EVM 9.7%
	QPSK/ 2 GBd/s	3 m	BER 10^{-8}





Antes et. al. EuMIC 2011

Conclusions from July 2012 Tutorial to the IEEE 802 Plenary

- Recent achievements in technology development have clearly shown that building wireless systems with ultra-high data rates @ carrier frequencies of 300 GHz and beyond is feasible.
- First successfull demonstrations of wireless data rates 25 Gbit/s over a distance of 10m
- Various applications feasible for THz communications are under consideration in numerous research projects
- Although some sharing issues still exist, the assumption can be made that appropriate spectrum is available.

Working towards a Study Group targeting wireless 10x Gbps ….

Part I: Some Boundary Conditions

Based on slides presented to IEEE 802.15 WNG in March 2013
(15-13-0130-01-0thz-launching_a_study_group_on_thz)

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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.

Consumer Market vs. Commerical 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 seems to be more appropriate to start with.

Working towards a Study Group targeting wireless 10x Gbps ….

Part II: Investigating possible Applications

Based on slides presented to IEEE 802.15 WNG in March 2013
(15-13-0130-01-0thz-launching_a_study_group_on_thz)

Selection of Possible Applications

	1.) Fixed links	2.) Data center links	3.) Intra device	4.) Kiosk	5.) WPAN	6.) WLAN
Multipath propagation	None		High; sup-pressible	Low	Medium-high	
Dynamics	None			Low	Medium	
Control over environment and TX/RX placement	High			Medium	None	
Beam alignment	Once during setup; manual			Not necessary	Initial alignment and tracking; automatic	
Multiple stations	No	Yes, time multiplex	No	No	Yes	
Access	Possible in THz band			Via conventional radio technology		

Type (a): No dynamic beam alignment, THz access, point-to-point

Type (b): Type (a) + conventional radio access

Type (c): Dynamic beam alignment, conventional access, multi-user

Source: IEEE 802.15-15-13-0119-00-0thz

Working towards a Study Group targeting wireless 10x Gbps ….

Part III: Some thoughts on Wireless Data Centers

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Based on 15-13-0130-01-0thz-launching_a_study_group_on_thz and
15-13-0411-00-0thz-Literature Review on Requirements for Wireless Data Centers

Today‘s situation at data centers

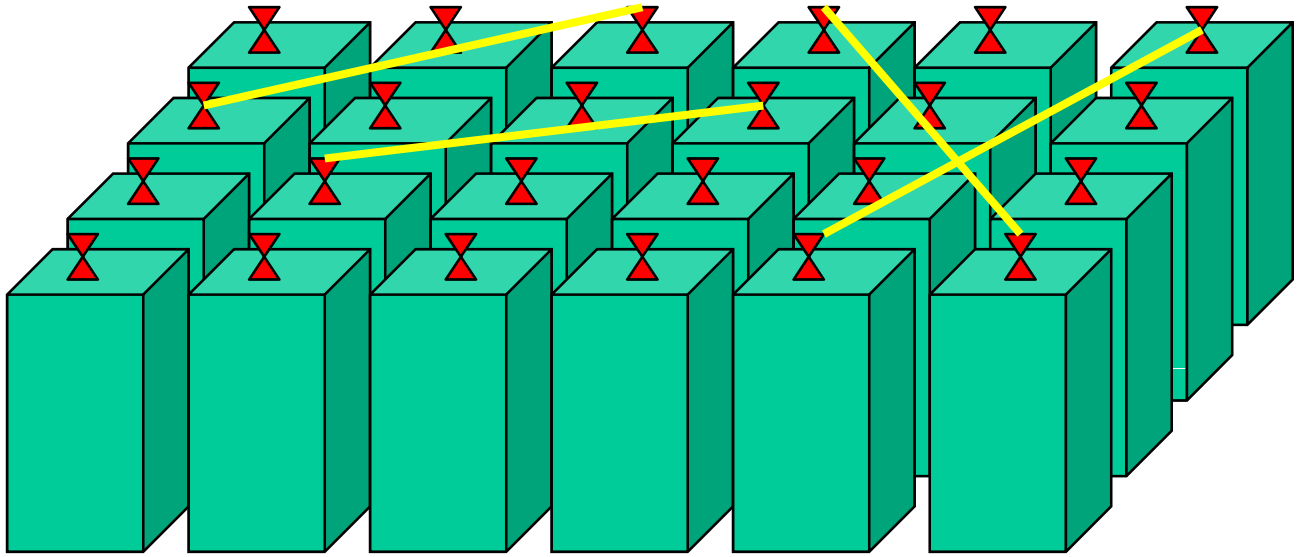
- Due to rapid data explosion more data centers are required
- Data intensive systems may have hundreds of thousands of computers yielding enourmous requirements for aggregate network bandwidth
  - In 2009 Google had 10 milion servers
  - Microsoft had 50000+ servers in their data centers
- Architecture 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 interconnections to 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

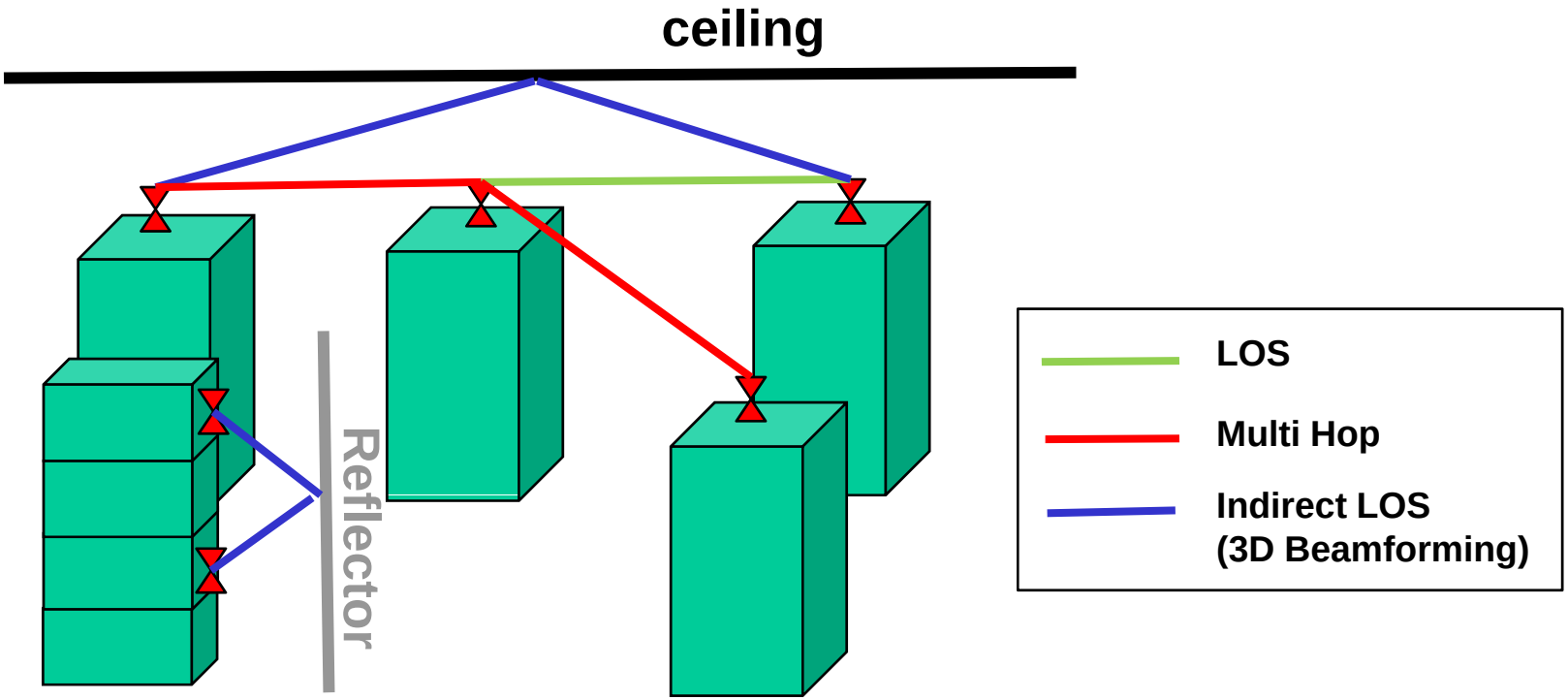


Some properties of wireless connections in data centers

- 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]

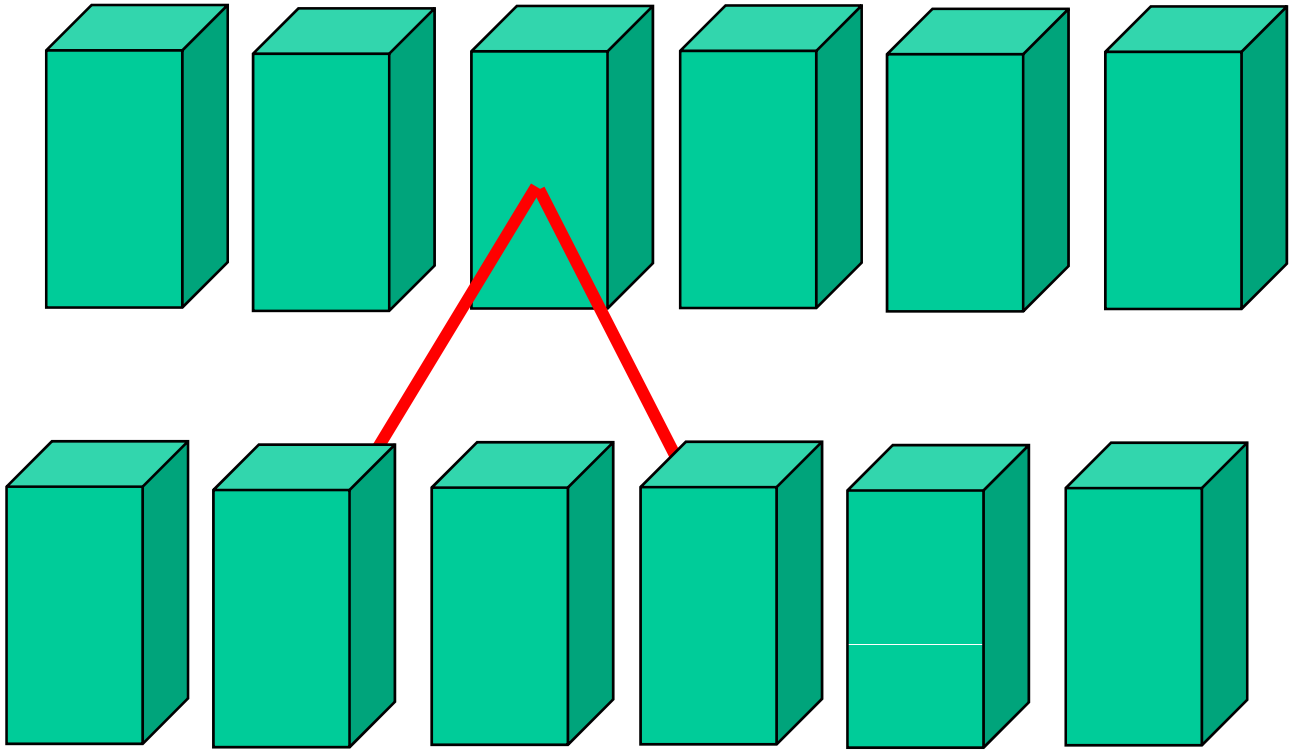
LOS and Indirect LOS Paths [7,10]



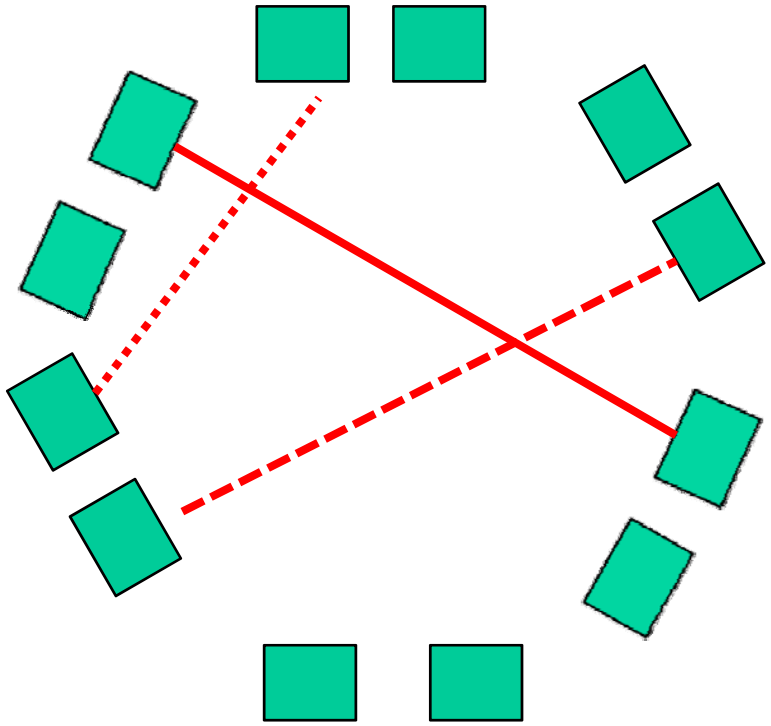
Hardware Components required for 3D Beamforming via Ceiling [7]

- Beamforming capabilities both in azimuth and elevation
- Ceiling reflectors (aluminium plates or other good reflecting materials)
- Electromagnetic absorbers on top of the racks to prevent local reflection/scattering around the antenna

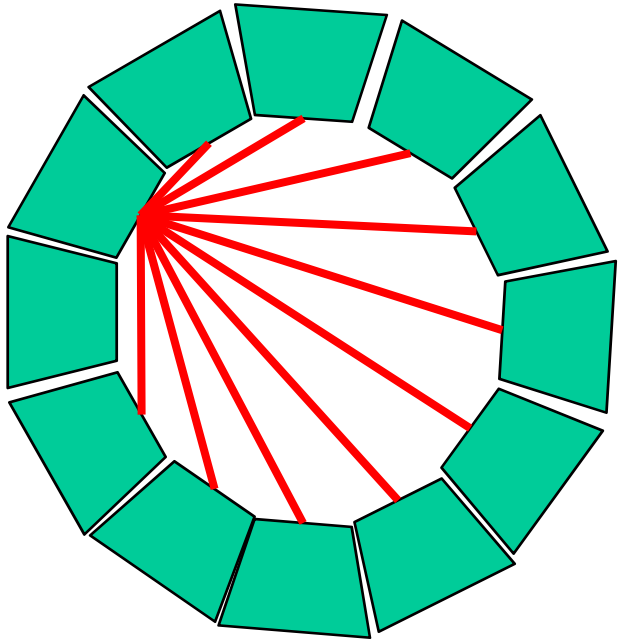
Node Arrangements – Two Parallel Rows [5]



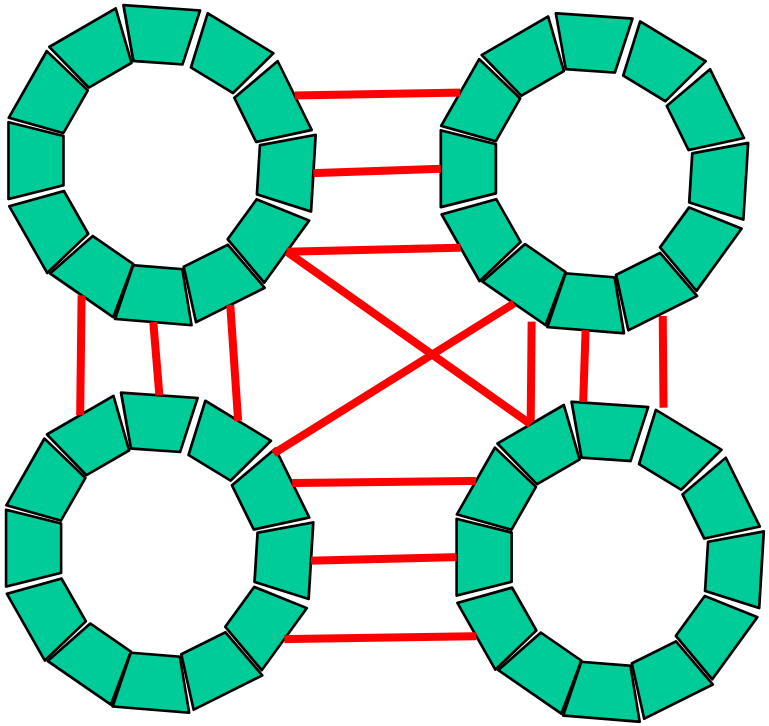
Node Arrangements – Hexagonal Shape [5]



Caley Data Center Design [12]



Intra-Rack Links



Inter-Rack Links

Implications on other applications for THz Comunications

- Standardization of a THz systems suitable for wireless data centers can pave the way for other applications, e.g. wireless backhauling and intra-device communication
- All these applications may be grouped together by a standard on **„Beam switchable wireless point-to-point 40/100 Gbps links“**
- Availability of cheaper CMOS technology will enable the adoption of the standard to nomadic mass-market applications, e. g. gaming

Working towards a Study Group targeting wireless 10x Gbps ….

Part IV: Investigating on which MAC to build on

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Comparison of the Standards

Capability	IEEE 802.3	IEEE 802.11n	IEEE 802.11ad	IEEE 802.15.3c
Access				
Data transmission				
Disassociation				
Security				
Roaming				
Power saving				
Channel estimation				
Adaptive modulation				
Beam control				
Coexistence				
Robustness	−−−	+++	+++	++
Overhead	+++	−−−	−−	o

Provided

Not provided

Missing beam-forming support in 802.11n

802.15.3c preferable over 802.11ad due to lower overhead

802.3 appropriate for fixed links with stable, predefined conditions only; very low overhead

Working towards a Study Group targeting wireless 10x Gbps ….

Part V: Some thoughts on the PHY

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Principle Possibilities to achieve Wireless 10x Gbps

- Further development of 60 GHz systems by enhancing spectral efficiencies
- Use FSO or Optical Wireless Communications
- Use more spectrum and apply moderate spectral efficiencies => enough frequency spectrum available beyond 300 GHz only

Working towards a Study Group targeting wireless 10x Gbps ….

Part VI: Motion to form a Study Group

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Motion to form a Study Group

- At the July 2013 Plenary *The Terahertz Interest Group (IG THz) wished to start a study group with the scope of determining the validity of a standard on "100G (100 Gbit/s over beam switchable wireless point-to-point links)". Potential applications of interest include wireless data centers, wireless intra-device communication, and wireless backhauling. The wave length of interest for the PHY will be millimeter-wave or shorter. The recommendation of the study group will be to amend the standard802.15.3.*

- The SG has been approved by the EC

Current Status of the Study Group

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Outcome of the 1st Meeting in Nanjing September 2013

- SG Leadership has been completed:
  - Chair: Thomas Kürner (TU Braunschweig)
  - Vice-Chair: Iwao Hosako (NICT)
  - Secretary: Cai Yunlong (Huawei)
  - Technical Editor: Rick Roberts (Intel)
- Press Release on the formation of the new study group has been discussed.
- Initial Working **Draft for PAR and 5C** have been created (Documents 15-13-0522-01-0thz and 15-13-0523-01-0thz, supporting Document 15-13-0561-01-0thz,)
- Work on the **Technical Expectation Document** (TED)“. The content of the TED has been discussed and updated (Document 15-11-0745-10-0thz)

Joint Work with IEEE 802.1

- Looking at the targeted application Bridging is an issue
  - For sure in Wireless Data Centers
  - Potentially also in the wireless backhauling/fronthauling applications
- The development of a standard for wireless 100G puts us in a green field situation with the chance to consider bridging right from the beginning
- First item to discuss is the compatibiliy item in the 5C document.
  - Possible joint meeting at the Interim Meeting in January 2014

Planned Time Line

- November 2013 Plenary:
- 1st joint meeting with 802.1

- January 2014 Interim:
- 2nd joint meeting 802.1
- Finishing complete draft PAR and 5C ready for WG approval and submission to EC

- March 2014 Plenary:
- Adressing comments and getting PAR and 5C done

- May 2014 Interim
- Potential Kick-off of a Task Group

List of References (1/2)

[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

List of References (2/2)

[8] D. Halperin et. al, „Augmenting Data Center Networks with Multi-Gigabit Wireless Links“, SiGCOMM 2011

[9] „On the feasibility of Completely Wireless Data Centers“, http://www.cs.cornell.edu/courses/cs6452/2012sp/papers/cayley.pdf

[10] K. Ramchadran„60 GHz Data-Center Networking: Wireless Worry less?“, 2008

[11] Y. Cui at. Al, „ Channel Allocation in Wireless Data Center Networks“, IEEE INFOCOMM 2011

[12] Y. Cui at. Al, „ Wireless Link Scheduling for Data Center Networks“,ICUIMC‘11, February 21-23, 2011, Seoul, Korea