Terahertz-based ultra-high bandwidth
wireless access networks

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TERAPOD project newsletter #4

December 2019

Welcome to the fourth TERAPOD project newsletter!

This newsletter includes items covering:

- Announcement of the 3rd Towards THz Comms Workshop organised by the B5G Cluster
- Simulations of data link layer and synchronisation aspects for data centre network terahertz links by WIT
- Waveguide-based horn antenna work at INESC TEC
- Call for papers: Special Issue of Applied Sciences on THz comms

More info is available on the project website
www.terapod-project.eu

3rd Towards THz Comms Workshop
12-13 Mar-2020; IMEC (Leuven)

SAVE THE DATE

Third Towards Terahertz Communications Workshop

An ICT Beyond 5G Cluster Workshop

https://terapod-project.eu/links/b5g-cluster/

SAVE the date: *12th – 13th March 2020,*
IMEC, Leuven, Belgium

Further Info. contact:
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There will be an evening reception on THU 12-Mar, and a workshop on FRI 13-Mar-2020 including guest speakers and a panel session. Full agenda will be released soon!

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Data centre network simulations

One of the main tasks of the TERAPOD coordinator TSSG (Telecommunications Software and Systems Group, part of Waterford Institute of Technology) is to investigate Data Link layer (DLL) aspects for terahertz links in data centre networks, *i.e.* between arrays of server racks. The relatively short communication distances for top of the rack (TOR) links require many aspects of DLL to be addressed for efficient communication among the TOR devices. Some of these aspects are shown in Fig. 1, including a framing module for frame length selection and packet splitting; an error control module for adding CRC blocks and retransmission; buffer management to store incoming frames with ACK handling; a MAC scheduler for efficient channel access and scheduling and link establishment among nodes and interfaces with the physical layer such as antenna and beam management.

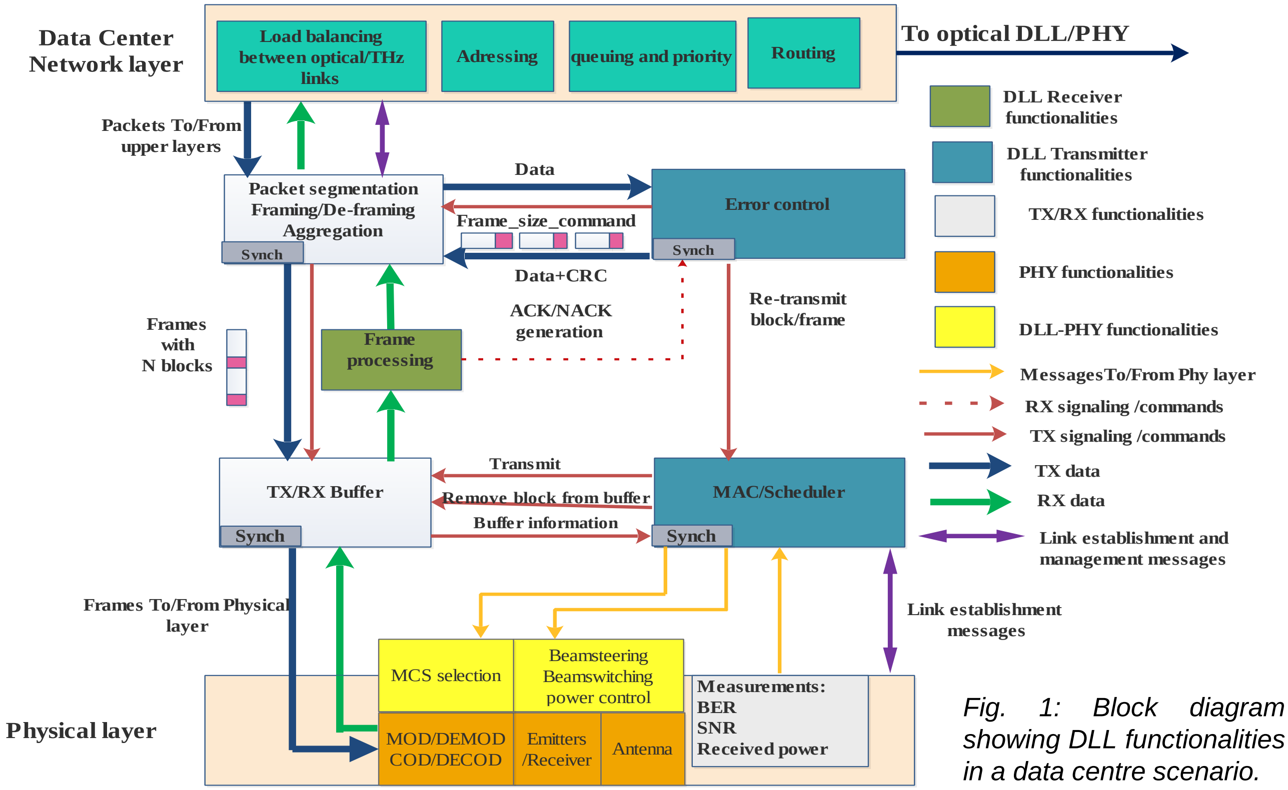

Fig. 1: Block diagram showing DLL functionalities in a data centre scenario.

The main performance indicators for a data centre communications link are throughput and latency. Throughput is modelled for a point-to-point scenario as given below, and also simulated in NS3 for TOR point-to-point links using parameters from real data centre scenarios.

$$R_u = -L_{block}\left(L_{header} + \frac{\lambda_p}{\lambda_f}\bar{L}_{packets}\left(1 + \frac{L_{CRC}}{L_{block}}\right)\right) \log(1\text{-}p)\frac{(1-p)^{L_{block}}}{1-(1-p)^{L_{block}}}\,\mu \qquad \text{(Eq. 1)}$$

L_{block}	Block size	L_{CRC}	Bits for CRC
K	Blocks per frame	p	BER
L_{header}	Bits per frame header	μ	Average transmitted fps

The results are shown in Fig. 2 which shows throughput as a function of bit error rate. It shows how DLL parameters can enhance useful throughput when error probability is high by combining block aggregation and retransmission. Figs 3 and 4 show the throughput and latency results for a point-to-point scenario, which uses 12.96 GHz bandwidth (standard) and shows that 9 Gbps throughput can be achieved for a distance of 1.4 m without using RTS/CTS messages and latency remains under the acceptable limit (<0.1 ms).

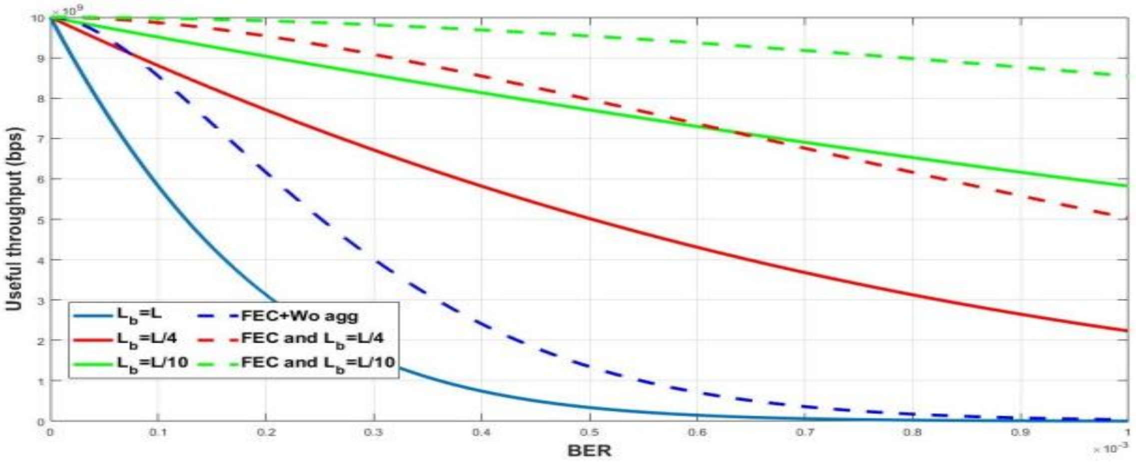

Fig. 2: Throughput as a function of BER.

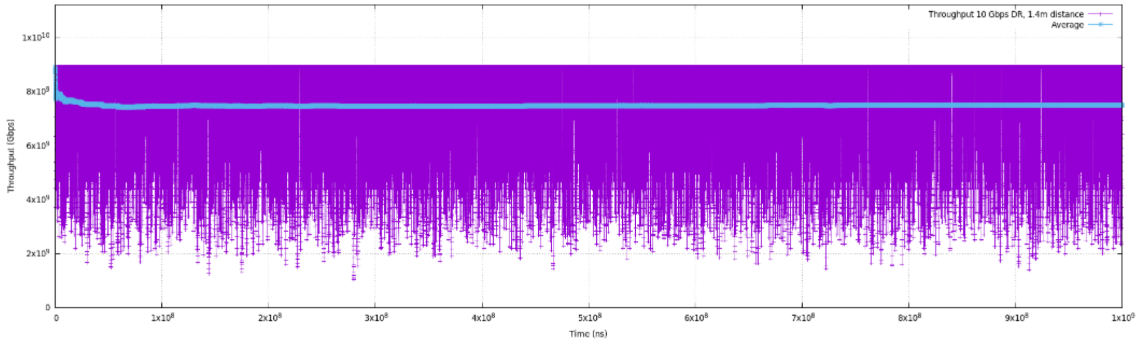

Fig. 3: Simulated throughput for TOR point-to-point link within a data centre.

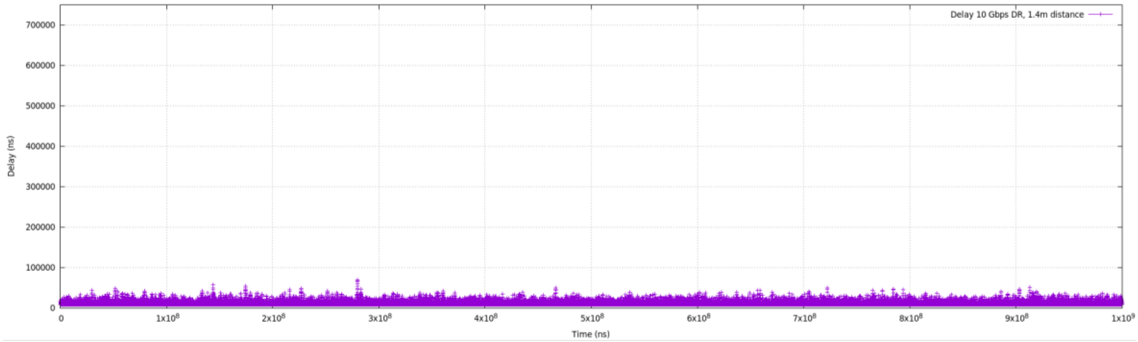

Fig. 4: Simulated latency for TOR point to point link within a data centre.

Noureddine Boujnah, Saim Ghafoor & Alan Davy have written three related 2019 conference papers:
"Modeling and Link Quality Assessment of THz Network Within Data Center," 2019 European Conference on Networks and Communications (EuCNC).
"Impact of channel errors and data aggregation on throughput in THz communications," ACM NanoCom 2019.
"Integrating THz Wireless Communication Links in a Data Centre Network," IEEE 5G World Forum.

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Synchronisation mechanism

Synchronization among the nodes is also required when directional antennas are used to schedule transmission efficiently among the nodes. A synchronisation mechanism is also proposed (shown in Fig. 5) for TOR nodes within a data centre in which each node stores information about the nodes in the network. The synchronisation duration was optimised for a given network of M×N TOR nodes, and it was shown that the minimum duration is achieved by synchronising first rows then columns. The total duration is:

$$T_{Syn} = (M + N - 2)(T_{sw} + 2\tau) \qquad \text{(Eq. 2)}$$

Where, T_{sw} is the switching time and τ is the transmission duration between two nodes during the synchronisation phase. Each node then transmits, according to its schedule in the communication. Phase node sectorisation is also applied to the network. Fig. 6 shows that the synchronisation period is minimised for the rectangular architecture with the alternating beam technique compared with the with other techniques which were simulated.

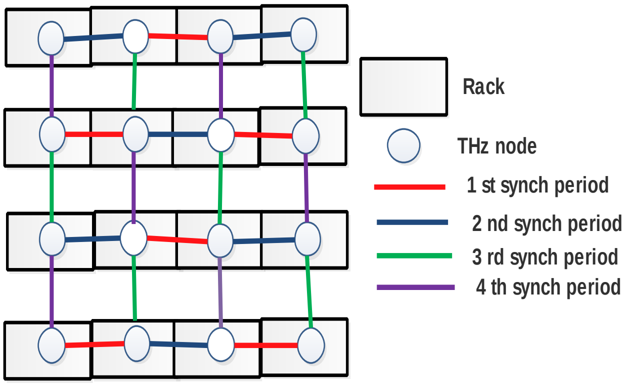

Fig. 5: 4×4 TOR architecture with link scheduling.

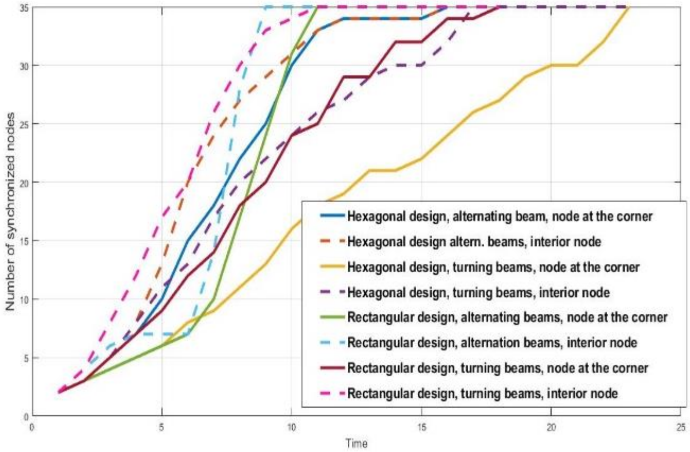

Fig. 6: Simulated synchronisation periods for different synchronisation mechanisms.

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Waveguide-based horn antenna

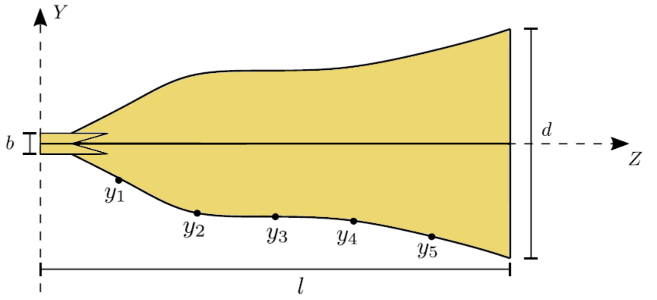
A waveguide-based Schottky barrier diode (SBD) receiver corresponds to one of the targeted developments in TERAPOD. To capture electromagnetic radiation within such waveguide-based devices, the best solution consists in a waveguide-based antenna, namely a horn antenna which can provide a high gain (better than 25 dBi) in order to mitigate the huge free space loss incurred by the 300 GHz link budget.

Although the diagonal horn antenna looks like a pyramidal horn with a square output aperture (see Fig. 7), its square output aperture is rotated 45° relative to the waveguide, which allows these horns to be machined as split-blocks and then joined to form the antenna. The gaussicity (*i.e.* Gaussian beam coupling efficiency) achieved by the diagonal horn antenna is approximately 84 %. Although this is less than the typical 98 % of corrugated horns, the manufacturing process is much simpler. Antenna gaussicity is a key parameter when quasi-optical processing of the beam is required (*e.g.* through lenses, reflectors, polarisation grids).

A new spline-profiled horn antenna design method has been proposed by INESC, which is scalable in length and aperture to achieve higher gains whilst retaining a high Gaussian efficiency. An approach is used where a particle swarm optimisation (PSO) is used to optimise the spline, using the gaussicities at the operating frequencies as the objective function, which improves side-lobe level and cross-polarisation when compared to the state-of-the-art.

With the proposed method, which was validated through finite element method (FEM) simulations in a high frequency structure simulator (HFSS), side-lobe level and cross-polarisation better than 40 dB and 48 dB were achieved, respectively, for a specified gain of 25 dBi. Since this model is scalable in terms of horn aperture and length, it allows a designer to control the gain and still retain the high gaussicity of the split-block spline-profiled diagonal horn antenna. This work has resulted in a patent submission and software registration, as well as a publication in the EuRAD conference at European Microwave Week 2019.

H. M. Santos, E. D. Lima, P. Pinho, L. M. Pessoa, D. Moro-Melgar and H. M. Salgado
Scalable High-Gaussicity Split-Block Diagonal Horn Antenna for Integration with Sub-THz Devices; 16th European Radar Conference (EuRAD 2019), Paris, France, p. 353-356 (2019).



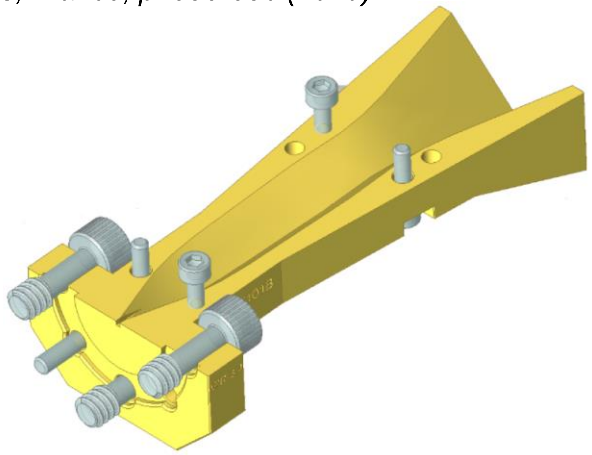


Fig. 7: (Above) Profile of the optimised antenna (Right) CAD model showing one of the two identical halves of the component, allowing simple manufacture.

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Call for papers: THz comms Special Issue

Dr. Mira Naftaly (NPL, UK) is Guest Editor of a Special Issue of Applied Sciences (MDPI) on THz communications, which will also be published as a stand-alone e-book. Please see:

https://www.mdpi.com/journal/applsci/special_issues/Terahertz_Communications_

The issue will be led by a review paper by Cyril Renaud (UCL and a TERAPOD partner). Submission deadline is 31-Mar-2020, but papers will be published as they are submitted, so please feel free to submit sooner. There is no limit on the number of pages.

If you are interested or have any questions please contact Mira Naftaly:
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