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Project: IEEE P802.15 Working Group for Wireless Speciality Networks (WSN)

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Abstract: This document describes a quasi-compliant IEEE Std 802.15.3d transmission for 160m Backhaul Link, which has been performed within the Horizon 2020 EU-Japan project ThoR.

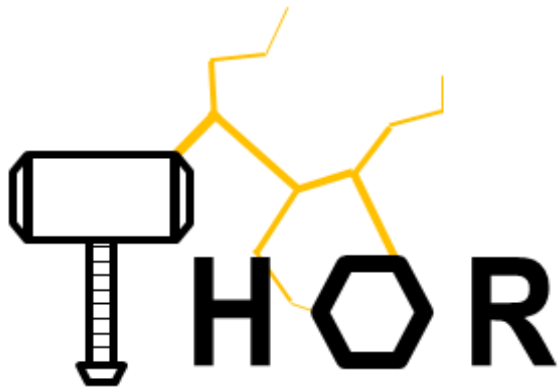
Purpose: Information of TG3ma

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This project is co-funded by

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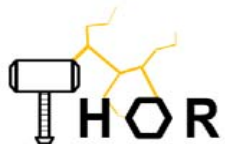
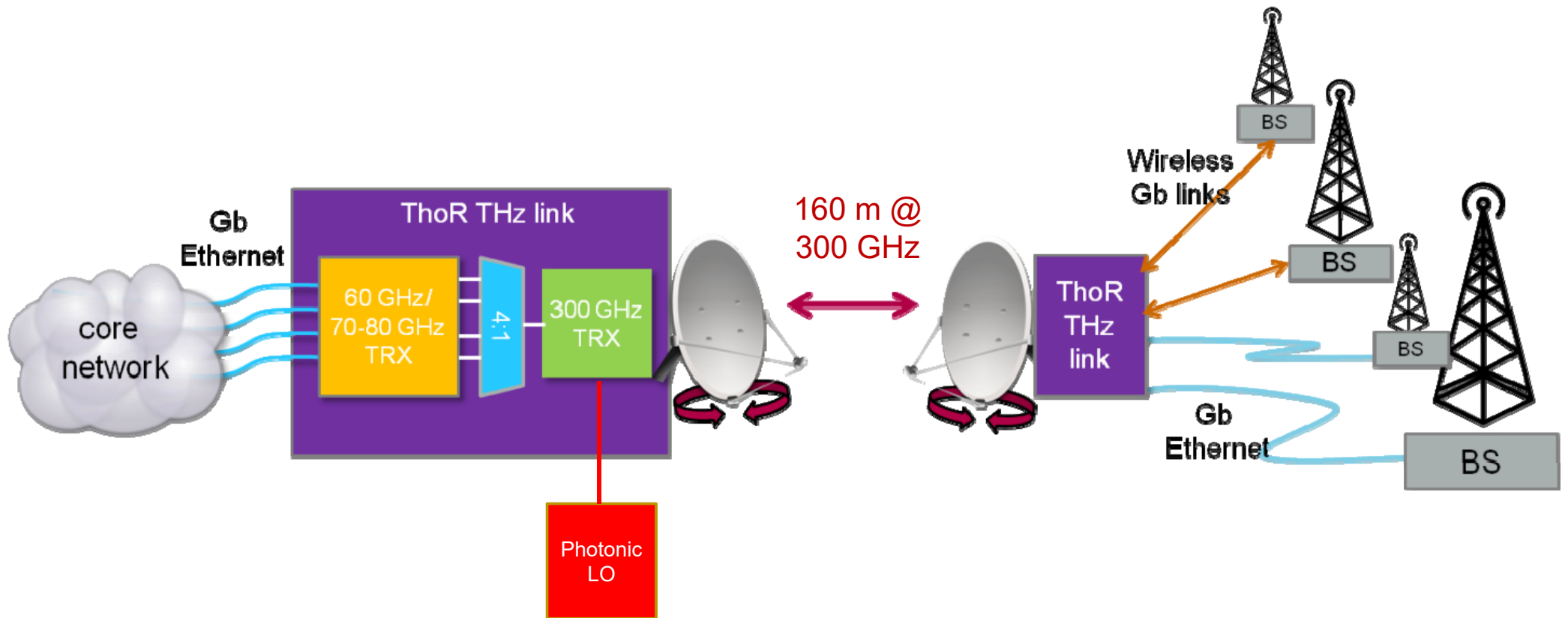
Demonstrating a quasi-compliant IEEE Std 802.15.3d transmission for 160m Backhaul Link

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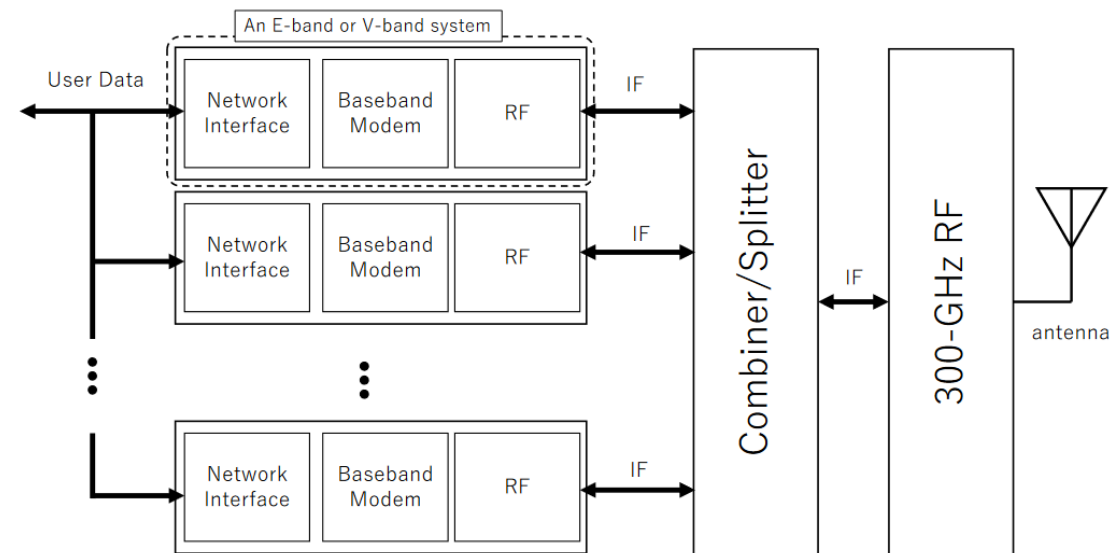
IEEE 802 Plenary, July 2022, Montreal

ThoR approach: Demonstrating the Capability of 300 GHz Backhaul/Fronthaul links



Networking Interface and Baseband Modem

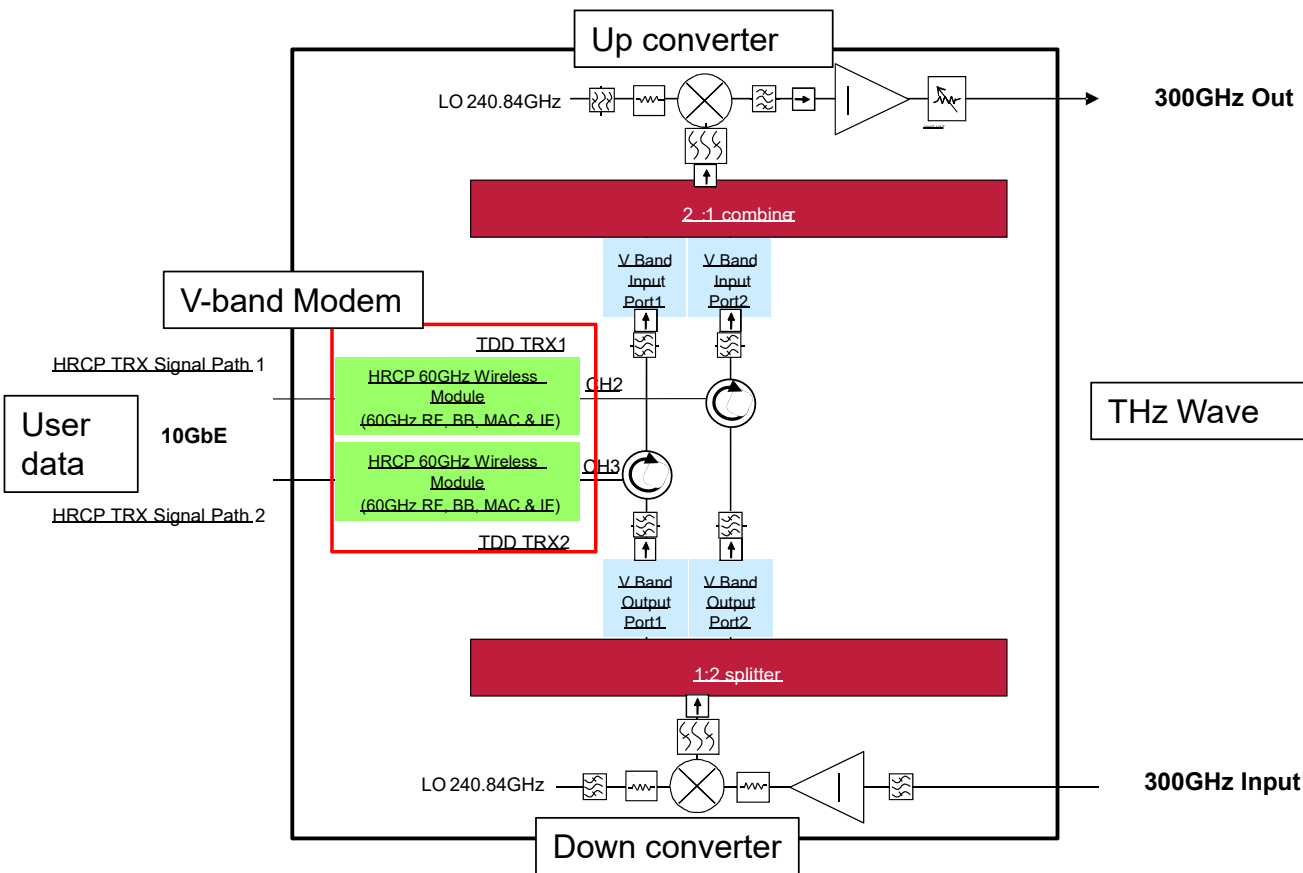
- The ThoR demonstrator uses a super-heterodyne concept where the RF signal of modems operating at 60 GHz and 70/80 GHz, respectively are used as the IF signal for the subsequent 300 GHz RF Front-end
- In the ThoR hardware demonstrator two types of modems have been used:
 - FDD modems
 - operating at 70/80 GHz
 - Up to for 4 2x2 GHz channels are aggregated
 - TDD modems (HRCP modems)
 - operating at 60 GHz and at a bandwidth of 2.16 GHz
 - used to demonstrate, that IEEE Std 802.15.3e with an extension of the IFS value is working for backhaul applications



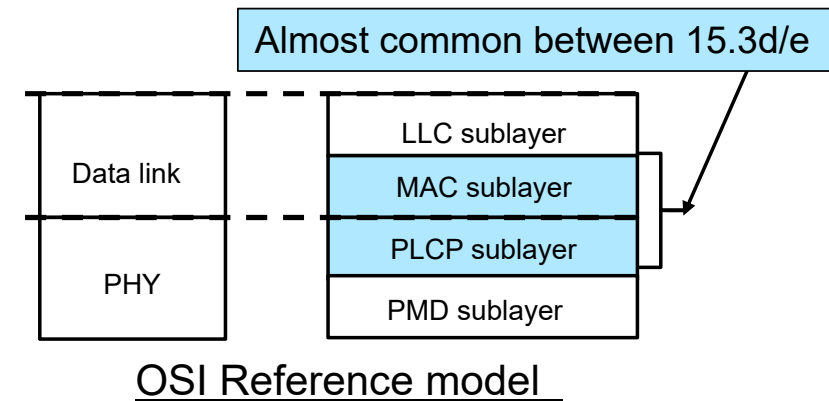
Source: ThoR Deliverable D3.5 available at <https://thorproject.eu/results/deliverables/.Testing> "Report of 60 GHz TRX Module"



Concept of demonstration system employing V-band modem



- The ThoR system with 60-GHz module is prepared to demonstrate wireless link that is **quasi-compliant with Terahertz standard, IEEE 802.15.3d**, by employing an existing **HRCP wireless module that is compliant with IEEE 802.15.3e**, which shares same MAC and part of PHY architecture with IEEE 802.15.3d.

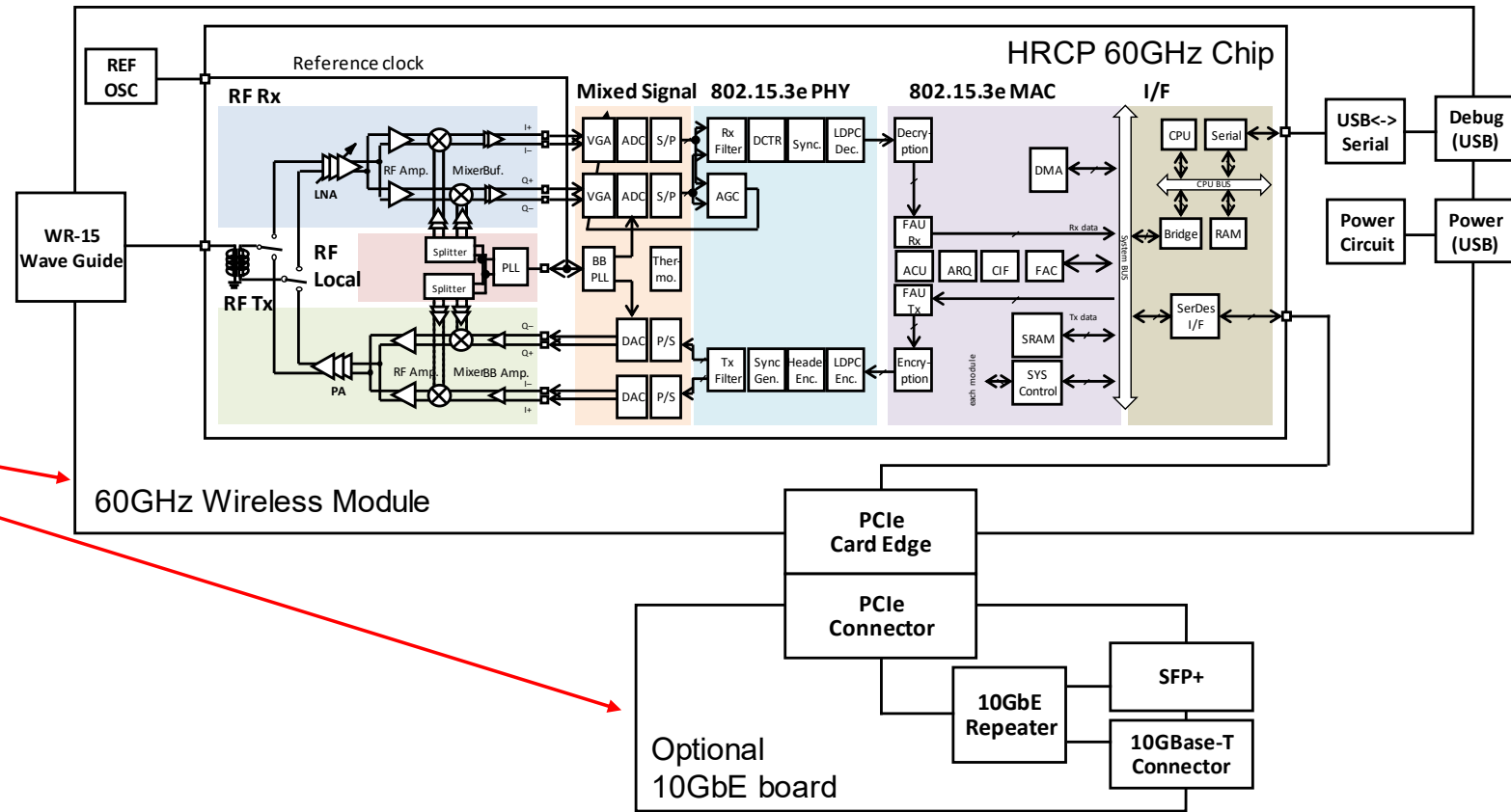
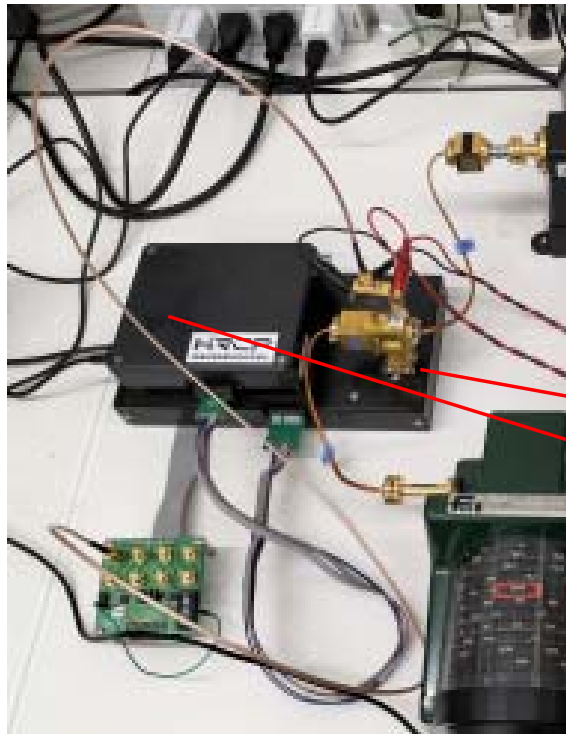


Example of THz transceiver with V-band modems

Source: K. Kondou: "Development of the ThoR 60 GHz transceiver module" ThoR Final Workshop <https://thorproject.eu/events/thor-final-workshop-and-demo/>

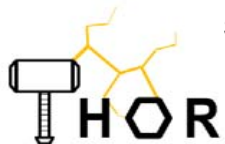


HRCP module(2nd version) overview

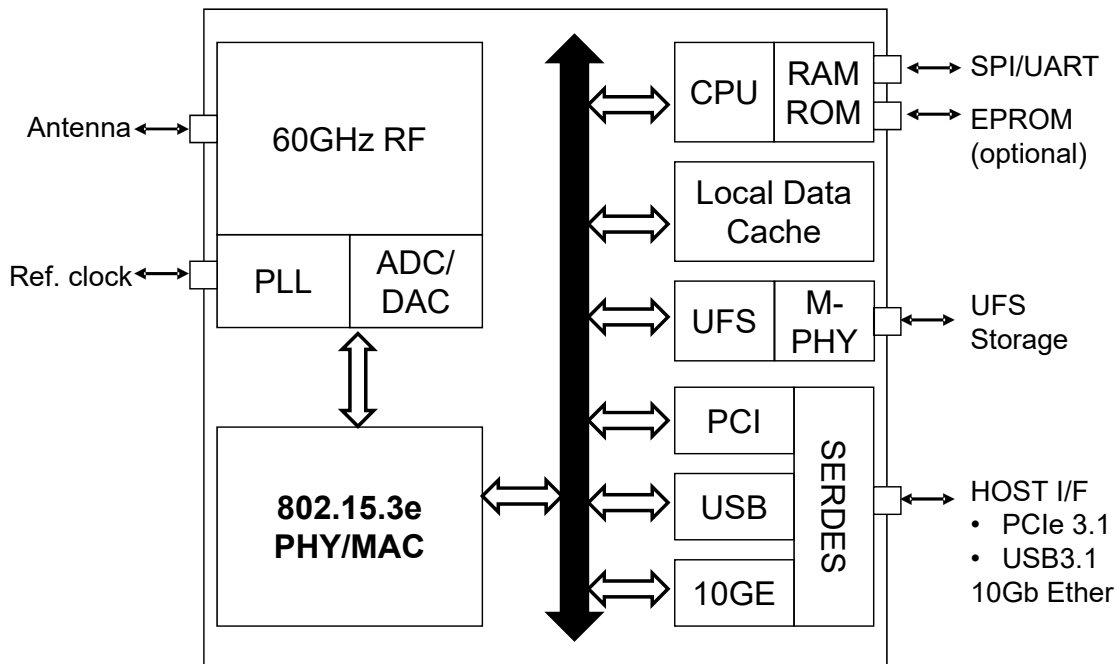


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HRCP TransferJet X SoC



TJX SoC functional Block Diagram

- **RF/PHY**

- ✓ **RF Bandwidth: 2.16 GHz**
- ✓ **RF channel: 60.48 and 62.64 GHz**
- ✓ Built-in Fractional PLL supports 19.2 to 52 MHz of reference clock
- ✓ Modulation: Single carrier, up to **16 QAM**
- ✓ **PHY rate up to 6.9 Gb/s**
- ✓ User-data rate: 1.5 to 6.1 Gbps

- **MAC**

- ✓ Dedicated HW for enabling **Fast link-setup**
- ✓ Supporting **bi-directional data transfer with TDD**
- ✓ Encryption support: AES 128bit with GCM
- ✓ **Built in RISC CPU** with on-chip RAM and ROM

- **I/F**

- ✓ **PCI express 3.1** device I/F
- ✓ **USB 3.2 gen 2** device I/F
- ✓ **UFS 2.1 host I/F** for optional data cache
- ✓ **IEEE 802.3-2005(10GE)** with IEEE 1588 PTP function

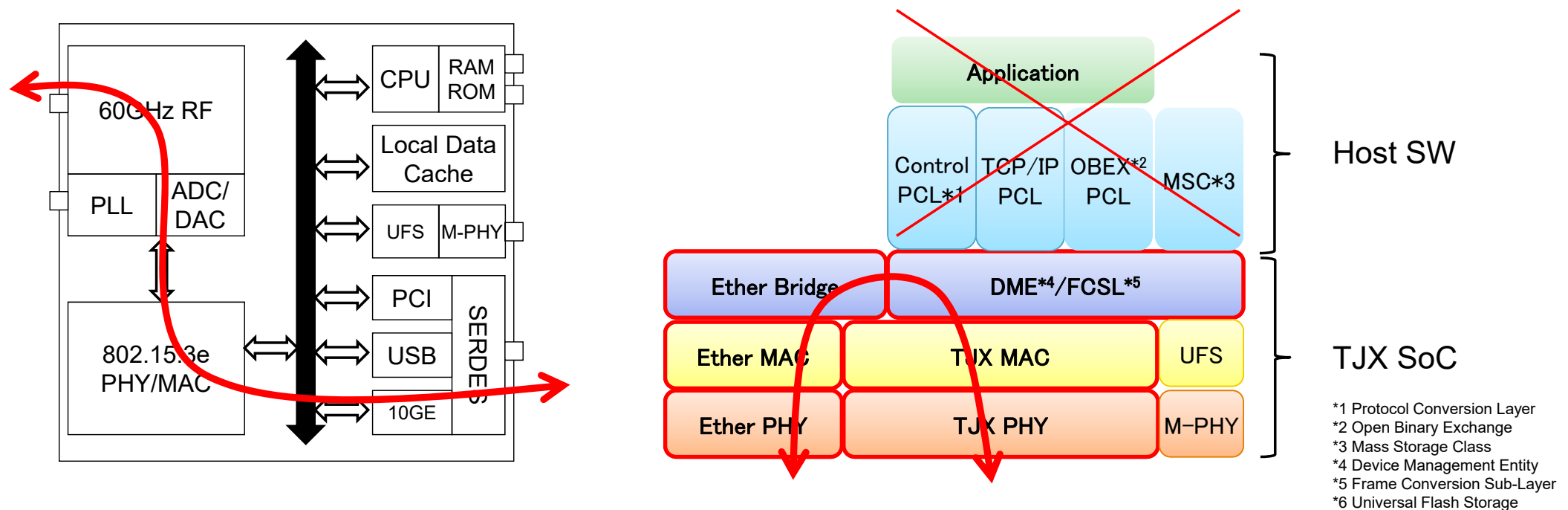
Source: K. Kondou: "Development of the ThoR 60 GHz transceiver module" ThoR Final Workshop <https://thorproject.eu/events/thor-final-workshop-and-demo/>

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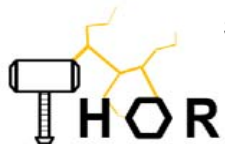
Ethernet bridging with TJX SoC

Once the SoC is configured to Ethernet Bridge mode, all frames are transmitted through 60GHz without any external control.



Source: K. Kondou: "Development of the ThoR 60 GHz transceiver module" ThoR Final Workshop <https://thorproject.eu/events/thor-final-workshop-and-demo/>

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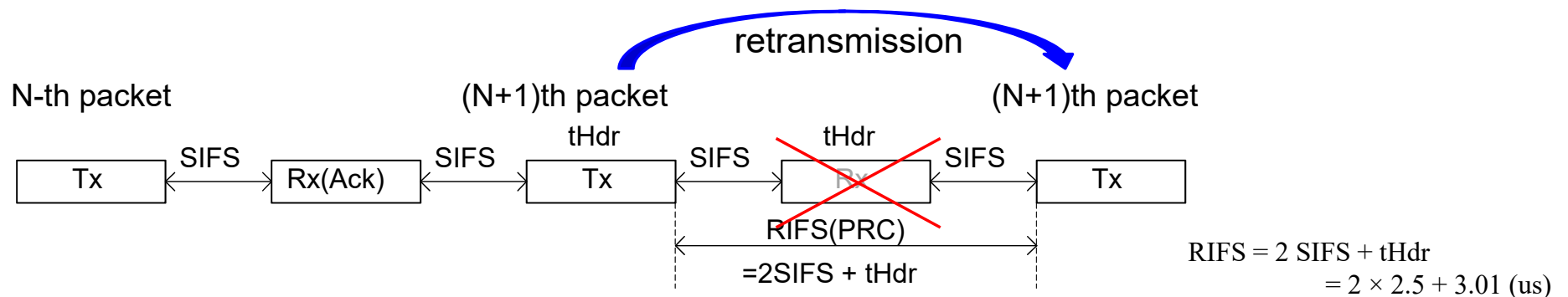


Issue found on RIFS value in IEEE 802.15.3d/e

In this project, we also found that some modification required to current IEEE specification, for achieving **long-distance link**.

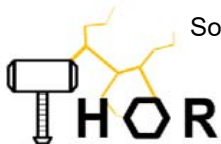
The **modification to RIFS** is also proposed to current standardization activities in IEEE 205.15 TG3ma. What is RIFS?

- Retry Inter Frame Space(RIFS) is a time between an frame and its retransmission frame.
- All frames are retransmitted when no response is observed from receiver.



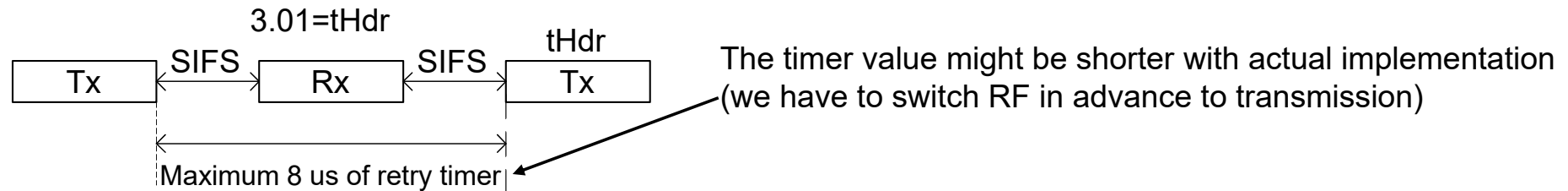
Source: K. Kondou: "Development of the ThoR 60 GHz transceiver module" ThoR Final Workshop <https://thorproject.eu/events/thor-final-workshop-and-demo/>

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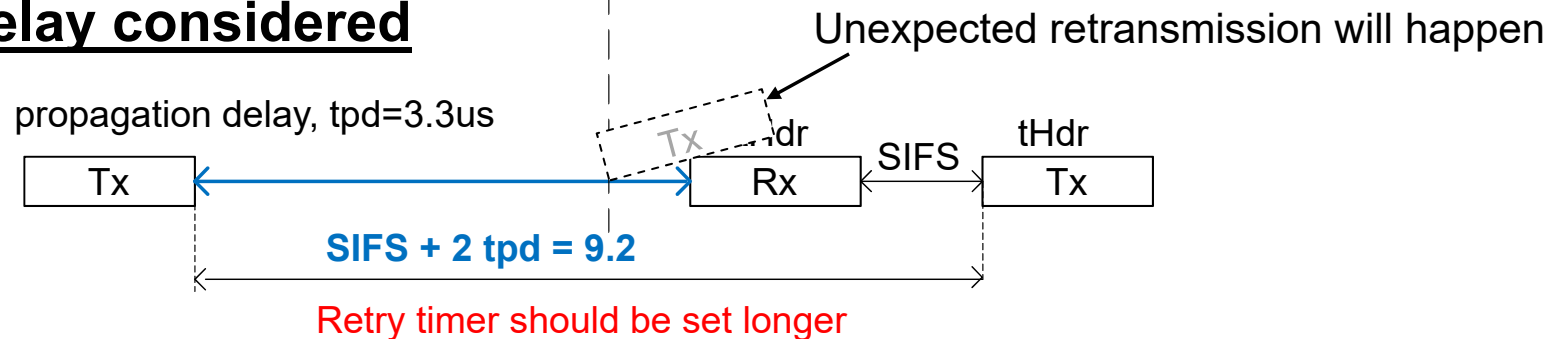


Considering long propagation delay

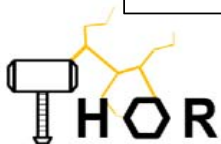
ideal case



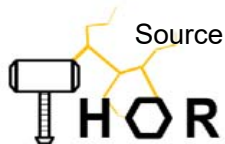
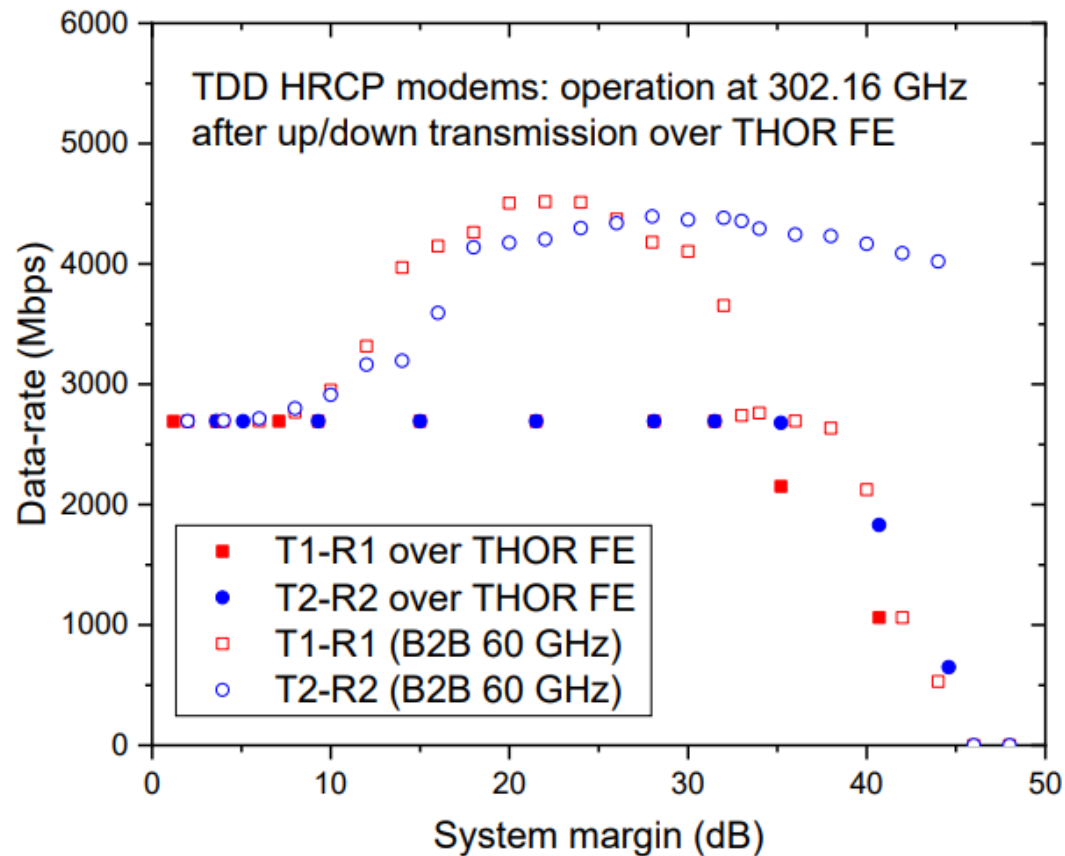
1-Km delay considered



Somehow, RIFS should be set to be more longer time duration than current specification.



Pre-Demo Lab Test of HRCP modems with RF-Front-Ends



Source: ThoR Deliverable D4.7 to be published at <https://thorproject.eu/results/deliverables/>. Testing "Final report of the RF front-end developments"

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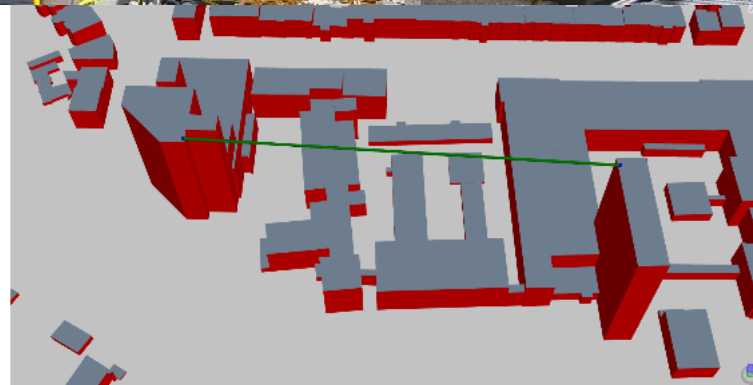
Final Demo Set-up at Campus of TU Braunschweig



Photo: Thomas Kürner/TU Braunschweig



Photo: Thomas Kürner/TU Braunschweig



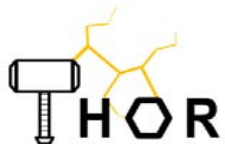
Link set-up and data transmission of 1 Gbps has been successfully demonstrated



```
rfpll_calibration3: selected bank: 9 (cal=817,tgt=815)
status = Good
time (us) = 32700163.736
transferred data (MiB) = 4096
data rate (Mbps) = 1050.751
```

Screenshot of the successful transmission

Demo of the complete Thor Hardware demonstration is available at
<https://cloudstorage.tu-braunschweig.de/getlink/fi5AwVviev4ykfeKH99KyXjQ/>



Thank you for your attention!

ご清聴ありがとうございました



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