ANALOG VS. NEXT-GENERATION DIGITAL FRONTHAUL: HOW TO MINIMIZE OPTICAL BANDWIDTH UTILIZATION

M. Hinrichs, L. Fernández del Rosal, C. Kottke, V. Jungnickel
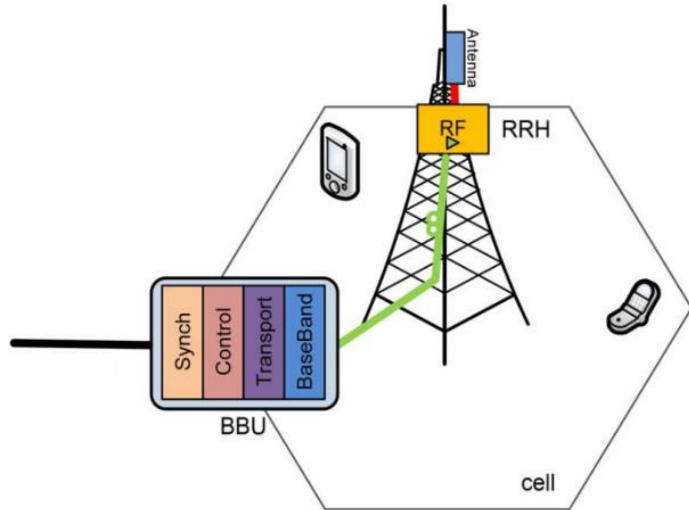
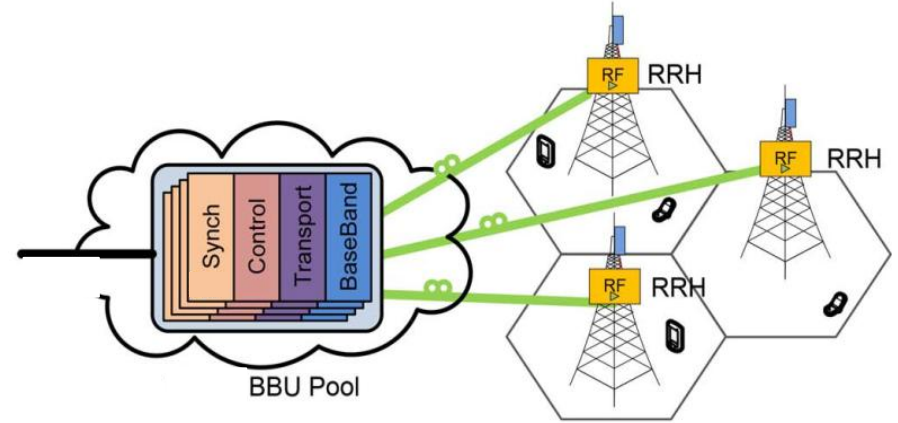RS2: Malte Hinrichs – Analog vs. Next-Generation Digital Fronthaul

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Overview

- **Introduction**
- Fronthaul Concepts
- Simulations
- Experiments
- Conclusions

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Introduction
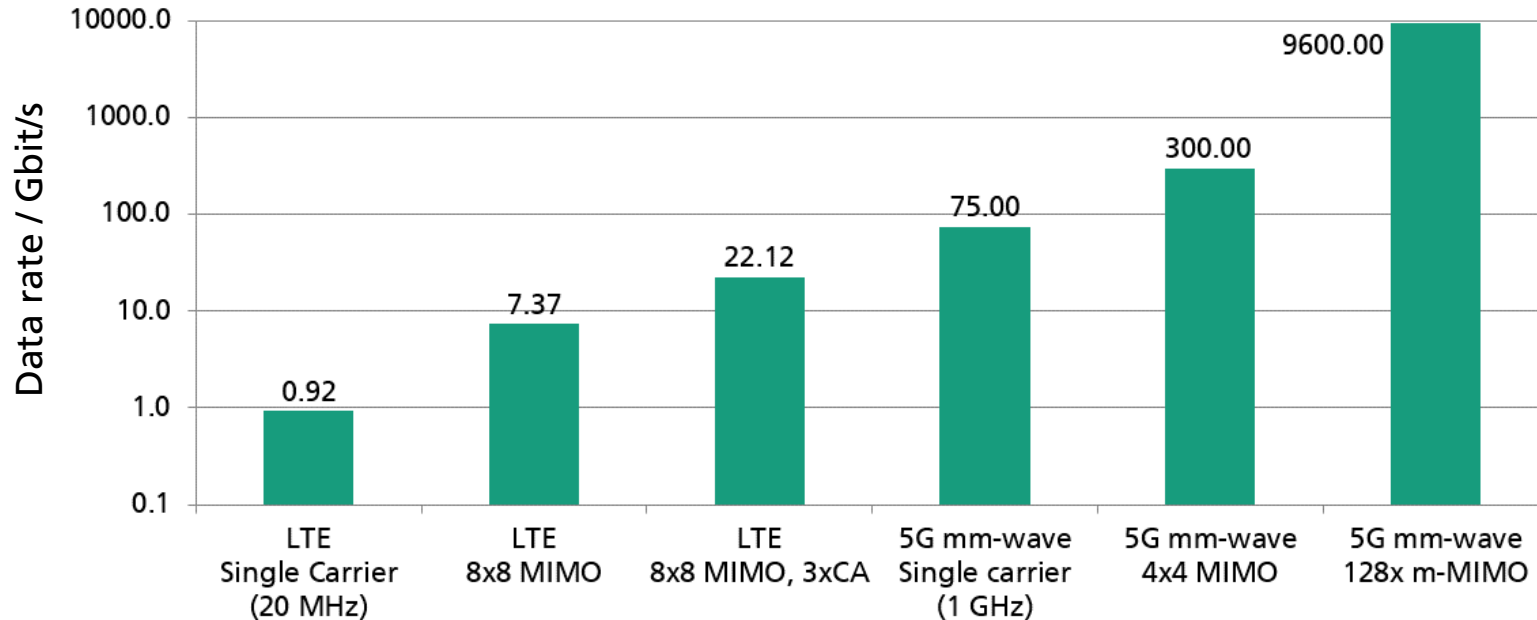## Cloud-Radio Access Network (C-RAN)

Distributed RAN

Cloud-RAN (C-RAN)

[1] A. Checko et al. 'Cloud RAN for Mobile Networks—A Technology Overview'. In:
IEEE Communications surveys & tutorials 17.1 (2015), pp. 405–426.

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Introduction
C-RAN fronthaul data rate requirement

→ New fronthaul solution needed for 5G!

[4] P. Turnbull et al., "D3.1 iCIRRUS - Verification of Ethernet as transport protocol for fronthaul / midhaul," 2015.

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Fronthaul Concepts
## Approaches for bandwidth reduction

- **Analog fronthaul**

  - Transport of analog baseband signals over fiber instead of digitized samples

- **Next Generation Digital Fronthaul**

  - New Functional Split: partial shift of baseband processing functions to RRH

  - Transport of higher-layer data over fronthaul ➡ lower data rate

> **Aim of this work**
> Performance comparison between
> analog and digital fronthaul regarding
> impact of chromatic dispersion

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Fronthaul Concepts
Analog Fronthaul (Downlink)
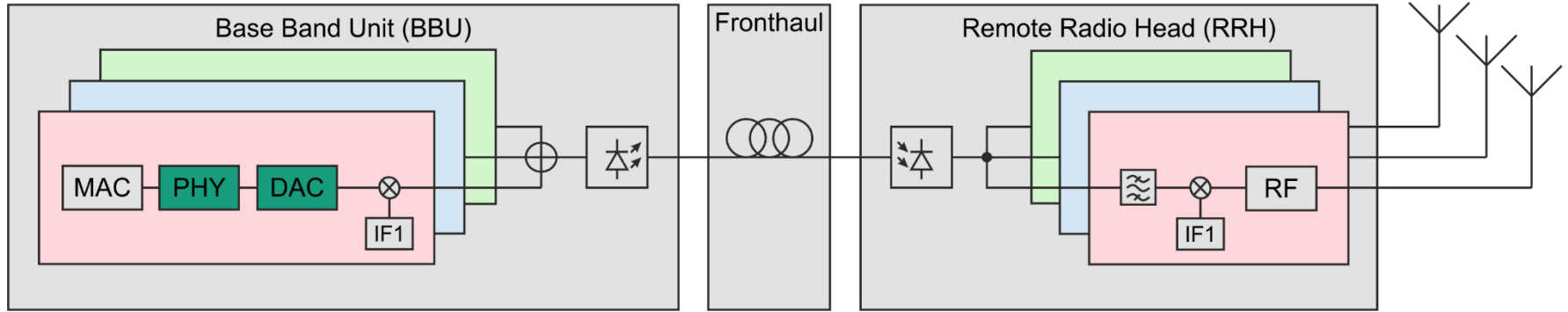
- Complete baseband processing at BBU, also DAC

- Multiple channels at separate intermediate frequencies (IF), electrical mixing

- Analog electrical signal modulated onto an optical carrier

- Only signal conversion, RF components at RRH

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Fronthaul Concepts
Next Generation Digital Fronthaul (Downlink)
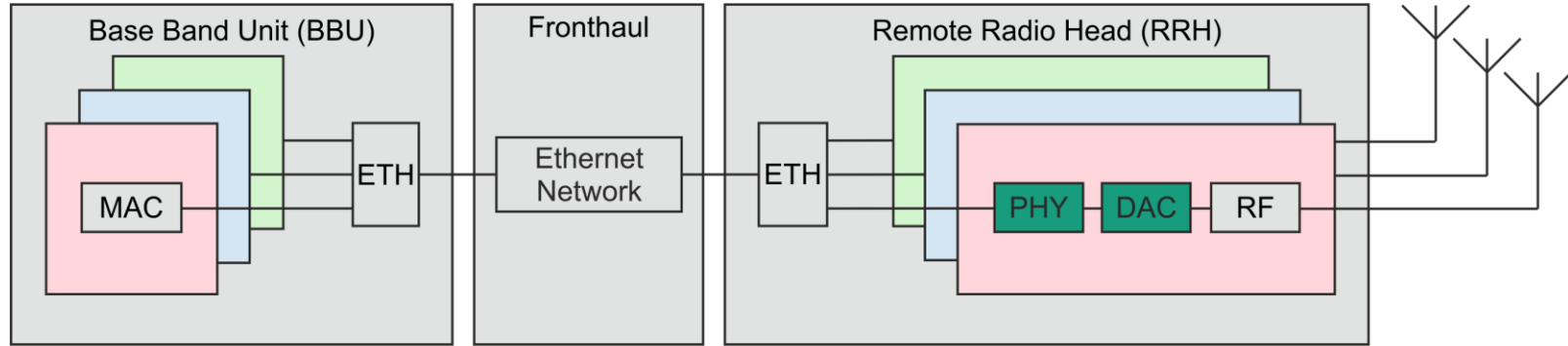
- Partial or complete shift of physical layer signal processing (PHY) to RRH

  - Here: split between MAC and PHY – MAC layer (and higher) centralized

- Transport of digital user and control data on the fronthaul (here: Ethernet)

- Data rate decreased by factor 30-50, load dependent

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Simulations

## Setup: Analog Fronthaul

- 4 channels, 2.5 Gbit/s each

- Fronthaul bandwidth:
  1.5 GHz/channel
  6 GHz overall

- Simulation of different
  fiber lengths with focus
  on chromatic dispersion

- Receiver connected back-
  to-back (no wireless span)

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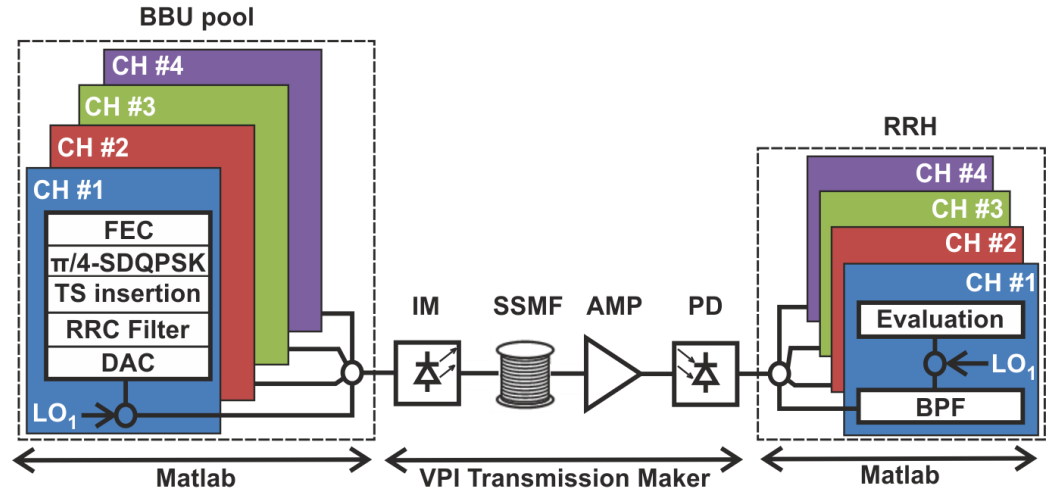
Simulations
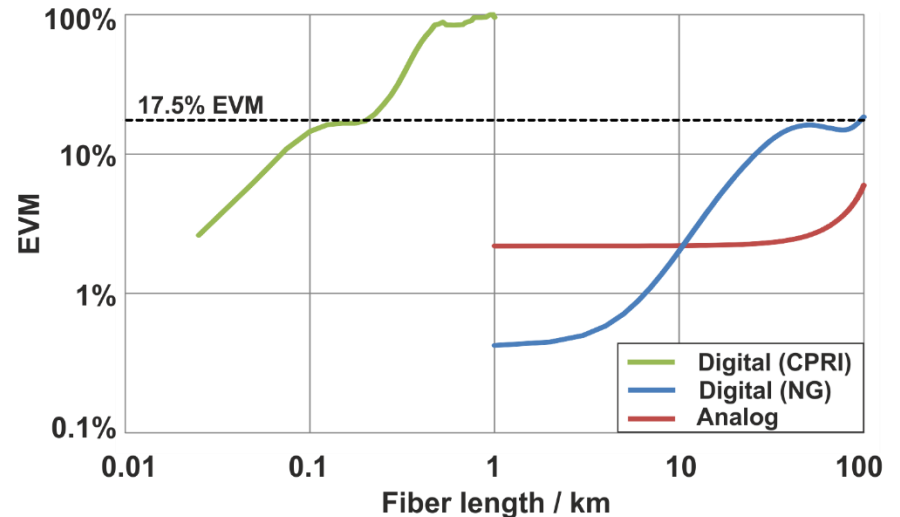## Setup: NG Digital Fronthaul

- Fronthaul:
  10 Gbit/s On-Off-
  Keying (OOK)

- Simulation of different
  fiber lengths, comparison
  to analog fronthaul

- Receiver connected to RRH

- Optical link identical
  to analog fronthaul

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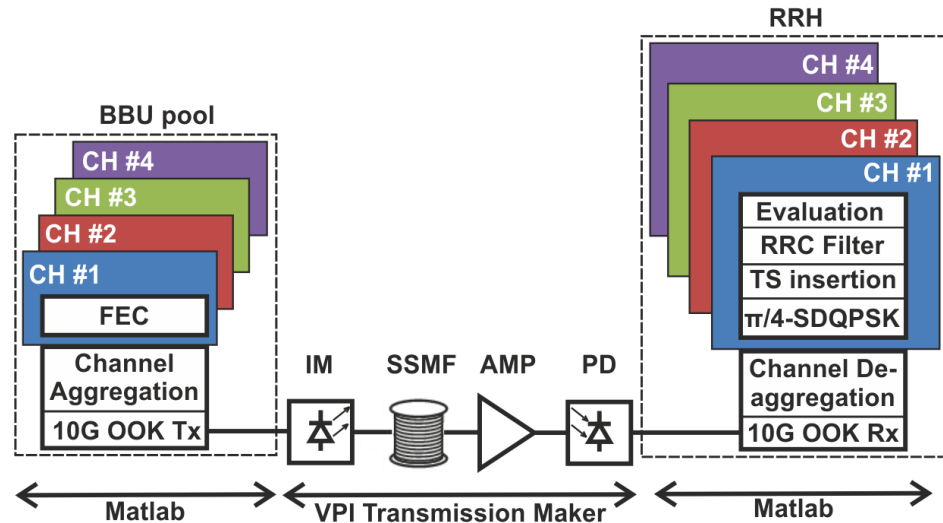
Simulation Results: Conventional/NG-Digital/Analog
EVM on a 10 Gbit/s radio signal

- „Conventional" CPRI solution

    - 200 Gbit/s OOK on FH required (10 bit per I/Q sample)

    - Signal distorted at **<1 km**

- **50 km range**: Performance of both NG Digital and Analog FH good

    - Analog FH more resilient against chromatic dispersion at longer range

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Experiments
Comparison Analog/Digital Fronthaul

- Fiber length: Limits of both solutions around 50 km

- Generally: **Digital** solution more resilient against **low Rx power**

  - Equal BER at **3-4 dB** below

- At 50 km (limit range): Lower BER for **analog** FH at powers >-8 dBm

  - Reason: noise limitation, less impact of chromatic dispersion (lower signal bandwidth)

Rx Power needed for BER < 10^{-4} (FEC trs.)

Fiber length	Analog	Digital
Back-to-back	-11.5 dBm	-15 dBm
25.5 km	-11 dBm	-14.5 dBm
51 km	-8.5 dBm	-12.5 dBm
76.5 km	Not reached	Not reached

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Conclusions

- **Analog and NG-Digital FH: both suitable** for reducing optical fronthaul bandwidth at a range <50 km

- **Next-Generation Digital FH**: better performance at low power levels

  - E.g. low-cost systems without optical amplifier at Rx

- **Analog FH**: performance of wireless system limited by impact on baseband signal

  - Suitable e.g. for indoor systems (room coverage, small cells)

- Deployment to be settled through **practical** and **economic** aspects

  - Mass-production of digital hardware generally more economic

  - Complex access network structure not feasible with analog FH

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