Transparent transport of wireless communication signals in Radio-over-Fibre systems

M. García Larrodé, A.M.J. Koonen, J.J. Vegas Olmos, G.J. Rijckenberg

COBRA Research Institute,
Eindhoven University of Technology

L. Dang Bao, I. G.M.M. Niemegeers
Delft University of Technology

10th European Conference on Networks & Optical Communications
July 5th – 7th, 2005
University College London, London, UK
Outline

- Introduction: Radio-over-Fibre system approach
- OFM link transparency
- Propagation delay
- Conclusions
Radio over Fibre
System Approach

- Central site = \textit{remote} radio medium access control
- Antenna site = \textit{dummy} analog transceiver-interface
- Optical path
  - Extension of radio domain access
  - Analogue transport of radio signals
  - Transparent for radio protocol stack
Physical Layer Requirements

- Frequency band → beyond 5GHz
- RoF technique → Optical Frequency Multiplication (OFM)
- Analogue RoF link → transparent transmission of radio signals
- Additional propagation delay → impact in access protocols
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Optical Frequency Multiplication (OFM)

Central Controller

Antenna Site

\[ E_{in}(t) = E_0 \cdot e^{j(\omega_0 t + \beta \sin(\omega_{sw} t) + \phi(t))} \]

\[ h_{MZI}(t) = \frac{1}{2} [\delta(t) + \delta(t - \tau)] \]

\[
\cos(\omega_0 \tau + \Delta \phi(t)) \cdot J_{2n}(2\beta \cdot \sin(\frac{\omega_{sw} \tau}{2})) \text{, for the even harmonics;}
\]

\[
\sin(\omega_0 \tau + \Delta \phi(t)) \cdot J_{2n-1}(2\beta \cdot \sin(\frac{\omega_{sw} \tau}{2})) \text{, for the odd harmonics; and}
\]

\[
1 + \cos(\omega_0 \tau + \Delta \phi(t)) \cdot J_0(2\beta \cdot \sin(\frac{\omega_{sw} \tau}{2})) \text{, for the 0th harmonic.}
\]

[Koonen et al, PNET 2003]
Carrying radio data signals

1310 nm

QAM Generator $f_{sc} = 1$ GHz

Input signals at 1GHz
After 4.4km MMF, at 17.8GHz:
16-QAM – 52Mbps $\rightarrow$ EVM < 4.7%
64-QAM – 78Mbps $\rightarrow$ EVM < 4.9%
EVM after MMF transmission

Input signals at 1GHz
Recovered after 4.4km MMF at 17.8GHz
OFM link transparency after MMF transmission

16-QAM Performance

64-QAM Performance

Input signals at 1GHz
Recovered after 4.4km MMF at 17.8GHz

SNR penalty $\approx 8.6$ dB
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Additional propagation delay

- Inserting an optical fiber between CS and AS:
  - additional propagation delay between base station/access point and terminals
  - may outrun timing boundaries of the MAC protocols and round trip delays
  - multiple radio access and duplexing parameters become key requirements for the design of a radio-over-fiber link, as they set delay and timing boundaries for optimal usage of resources

- Centrally scheduled MAC schemes
  - Relax fiber length constraints
  - Allow flexible bandwidth allocation
  - Dynamic control of the additional propagation delay
Example: IEEE 802.16-TDD

- Air interface for Broadband Wireless Access Systems
- PHY: 2-11 GHz and 10-66 GHz bands, > 120 Mbps
- Flexible TDD centrally scheduled scheme

- TDD $\Rightarrow$ adaptive bandwidth allocation for DL and UL
  - Tx/Rx and Rx/Tx transition gaps variable (# physical slots (PS))
  - Increasing # PS in the transition gaps (system parameters) $\Rightarrow$ longer optical path can be inserted
Example: IEEE 802.16-TDD

(4.4 km)

Capacity reduction vs. Fibre Length

- Frame Type 0.5ms: 8.8%
- Frame Type 1ms: 4.4%
- Frame Type 2ms: 2.2%
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Conclusions

- Radio-over-Fibre $\rightarrow$ broadband wireless access infrastructure
  - Wireless flexibility + fibre high capacity
- Analogue RoF link $\rightarrow$ link transparency
- Additional propagation delay $\rightarrow$ capacity reduction
- RoF technique $\rightarrow$ Optical Frequency Multiplication (OFM)