Technologies for future mobile transport networks

Pham Tien Dat¹, Atsushi Kanno¹, Naokatsu Yamamoto¹, and Tetsuya Kawanishi¹,²

¹National Institute of Information and Communications Technology, Japan
²Wasdea university, Tokyo, Japan
Outline

- Flexible fiber-wireless mobile fronthaul
  - Downlink system
  - Bidirectional transmission
- Seamless fiber-wireless for moving cells
- Multiple radios over fiber system
- Conclusion
Flexible fiber-wireless transport systems

Core network

BBU pool
BBU ↔ BBU ↔ BBU

Control office

MUX/DEMUX

RRH RAU RAU RAU

RRH RAU RAU RAU
Fiber-wireless convergence

Conventional optical-MMW link: Large latency, high power

Seamless optical and MMW connection: Low latency, low power
Operating principle

Optical fiber

\[ f = \left| \frac{c}{\lambda_1} - \frac{c}{\lambda_2} \right| \]

Microwave

Millimeter

E/O converter

Down.

Up.

LO

Microwave
Downlink system: experimental setup

VSA: Vector Signal Analyser
LNA: Low Noise Amplifier
ATT: Attenuator
OBPF: Optical Band Pass Filter

MZM: Mach-Zehnder Modulator
EDFA: Erbium-Doped Fiber Amplifier
VSG: Vector Signal Generator
PD: photo-detector

P. T. Dat et al., ECOC (2016)
Downlink system: experimental results

Performance versus received optical powers

Performance versus LTE-A signal powers

P. T. Dat et al., ECOC (2016)
Bidirectional system: experimental setup

Central Station

- VSG_1
- VSG_2
- DL LTE-A inter-band 1
- DL LTE-A inter-band 2
- Com.
- MZM
- EDFA
- VSA
- RoF Rx.

Remote Antenna Unit

- Remote Radio Head
- 10 km
- ATT
- PD
- PA
- ED
- LNA
- LNA

Frequency (MHz)

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Power (dBm)</th>
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<tbody>
<tr>
<td>830</td>
<td>-120</td>
</tr>
<tr>
<td>840</td>
<td>-100</td>
</tr>
<tr>
<td>850</td>
<td>-80</td>
</tr>
<tr>
<td>860</td>
<td>-60</td>
</tr>
<tr>
<td>870</td>
<td>-40</td>
</tr>
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</table>

Frequency (GHz)

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Power (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>8</td>
</tr>
</tbody>
</table>

Remote Radio Head

- VSA_1
- VSA_2
- DL LTE-A inter-band 1
- DL LTE-A inter-band 2
- VSG

Opt. MMW Gen.

Sync.

ED

Opt. MMW Gen.

Sync.

LO

96 GHz

92.5 GHz
Bidirectional: experimental results

- Successful bidirectional transmission for CA LTE-A signals
- Applicable for future 5G signal transmission (256-QAM with EVM < 3.5%)
- PONs can be applied for optical transport (ITU-T req. for PONs: 15 dB)

P. T. Dat et al., OFC (2015)
Seamless fiber-wireless for moving cells

Network control and moving cells
Proof-of-concept: experimental setup

DPMZM: Dual-parallel MZM
OBEF: Optical band pass elimination filter
OBPF: Optical band pass filter
ATT: Attenuator
P-S: Power Splitter
ISO: Isolator
PS: Phase shifter

DPMZM: Dual-parallel MZM
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Legend:
- CS
- LD
- MZM
- DPMZM
- OBEF
- EDFA
- OBPF
- ATT
- P-S
- ISO
- PS
- RAU
- VSA
- VSG
- PC
- AP
- RoF
- IF
- LO
- LNA
- TA
- RAU
- LO

Graphs:
- Power (dBm) vs. Wavelength (nm)

P. T. Dat et al., OFC (2016)
Proof-of-concept: experimental results

- Good performance for both backhaul and over in-train networks
- High-spectral efficiency, low fiber-dispersion, cost effective system

P. T. Dat et al., OFC (2016)
Multiple radios over fiber

Multi-RATs over seamless fiber-wireless system

- CPRI for fronthauling: bit rate $> 100$ Gb/s/cell.
- RoF: high-speed components, massive systems

Cooperation of optical and radio access networks

Data mapping using F-OFDM

Signal-1 $\rightarrow$ Subcarrier mapping $\rightarrow$ IFFT-1 $\rightarrow$ CP-1 $\rightarrow$ Subband-1 filter

Signal-K $\rightarrow$ Subcarrier mapping $\rightarrow$ IFFT-K $\rightarrow$ CP-K $\rightarrow$ Subband-K filter
Multiple radios over fiber: experimental setup

**Diagram Description**

- **LD** (Laser Diode)
- **VSG** (Vector Signal Generator)
- **MZM** (Mach-Zehnder Modulator)
- **EDFA** (Erbium-Doped Fiber Amplifier)
- **DPMZM** (Doped Polymer Mach-Zehnder Modulator)
- **IF** (Intermediate Frequency)
- **PD** (Photo-Detector)
- **ATT** (Attenuator)
- **OBPF** (Optical Band Pass Filter)
- **VSA** (Vector Signal Analyser)
- **LTE-A** (Long Term Evolution-Advanced)
- **IF Com.** (RF Combiner)
- **AWG** ( Arbitrary Waveform Generator)
- **PC** (Preparation Circuit)
- **Div.** (Divider)
- **OSCA** (Oscillator)
- **RRH** (Radio Remote Head)
- **RAU** (Radio Access Unit)
- **MFH** (Multi-Frequency Heterodyne)

**Key Components and Labels**

- **12 GHz** Frequency Doubler
- **20 km** Fiber Optic Distance
- **96 GHz** MFH
- **2.5 m** Cable Length
- **1 GHz** Frequency
- **25 GHz** Ratios
- **21 GHz** User

**Technical Details**

- **MZM**: Mach-Zehnder Modulator
- **EDFA**: Erbium-Doped Fiber Amplifier
- **VSG**: Vector Signal Generator
- **Com.**: RF combiner
- **PD**: photo-detector
- **Div.**: RF Divider
- **VSA**: Vector Signal Analyser
- **LNA**: Low Noise Amplifier
- **ATT**: Attenuator
- **(O)BPF**: (Optical) Band Pass Filter

**Wavelength and Power Chart**

- 1555.6 nm
- 1556 nm

**Power (dBm)**

- -90 dBm
- -70 dBm
- -50 dBm
- -30 dBm
- -10 dBm
- 10 dBm
Multiple radios over fiber: experimental results

F-OFDM Signal

LTE-A Signal

New RAT signal (OFDM/FBMC)
Summary

- **Seamless convergence** of fiber-MMW would be a potential solution for future mobile fronthauling when fiber cable is not available.

- **Convergence of WDM IFoF and linearly located distributed antenna systems** is very promising for high-speed communication to high-speed trains.

- **Co-design and cooperative fiber-radio access networks** would be the key for future MMW and massive MIMO mobile signal, and multi-RAT transmission.
This work was conducted as a part of the “Research and development for expansion of radio wave resources,” supported by the Ministry of Internal Affairs and Communications (MIC), Japan.

Thank you

ptdat@nict.go.jp

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