Radio-over-Fiber Quintuple-Play Service Provision for Deep Fiber-to-the-Home Passive Networks

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Outline

- **Motivation**

- **Deep FTTH network with legacy coaxial support**

- **Experimental deployment in a real FTTH network**

- **Open-house show-room demonstrator**

- **Conclusion**

Motivation

- In the last decade, user's bitrate demand has grown roughly 50-60% per year
- The broadband adoption is fast and (seems) very addictive:
    - 41% of UK users would rather keep Internet connection than TV [*]
    - 84% of German user in their 20s would rather give up their car or partner than the broadband connection [*]
- Fiber-to-the-home (FTTH) access is a flexible, future-proof access technology that enables the provision of Gb/s bitrates per user
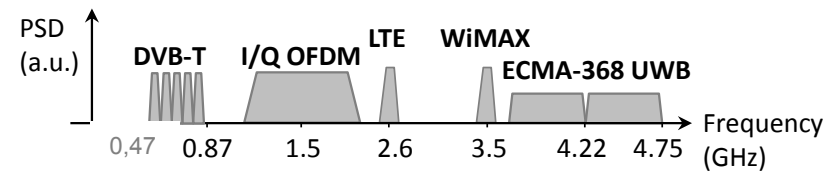

Downstream

FTTH

5-PLAY services

Upstream

Consumers	Enterprises
HDTV, on-line gaming, films, music…	File transfer
Enhanced interactivity, cloud computing, home management	HD video conf., could computing
Photos, videos…	Data back-ups

http://www.icc-opticalwireless.org
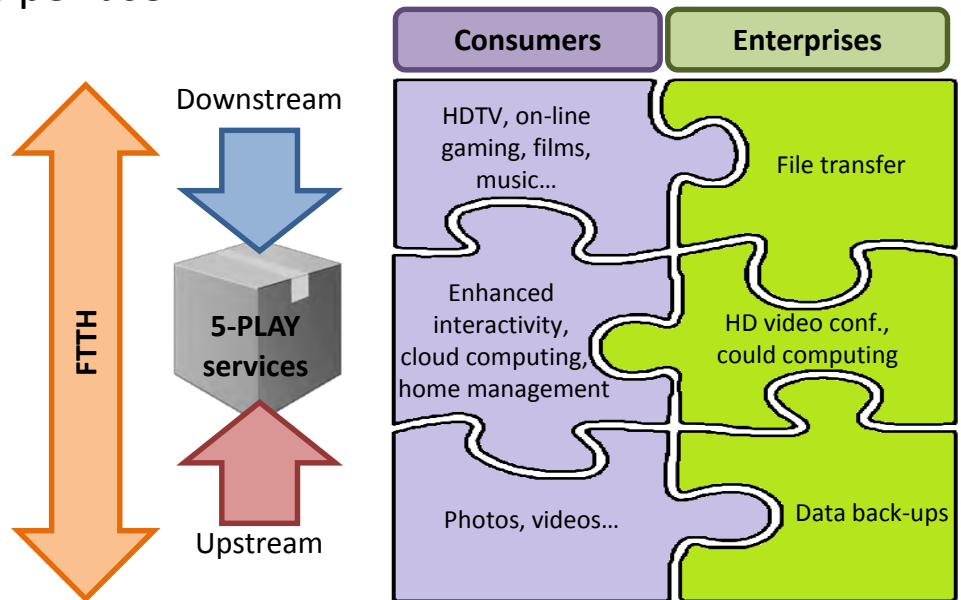
[*] FTTH Council Europe, "FTTH: shaping the future of a content-based world", white paper 2012

Quintuple-play service provision

- **FIVER optical access architecture is based on WDM LR-PON user provision :**
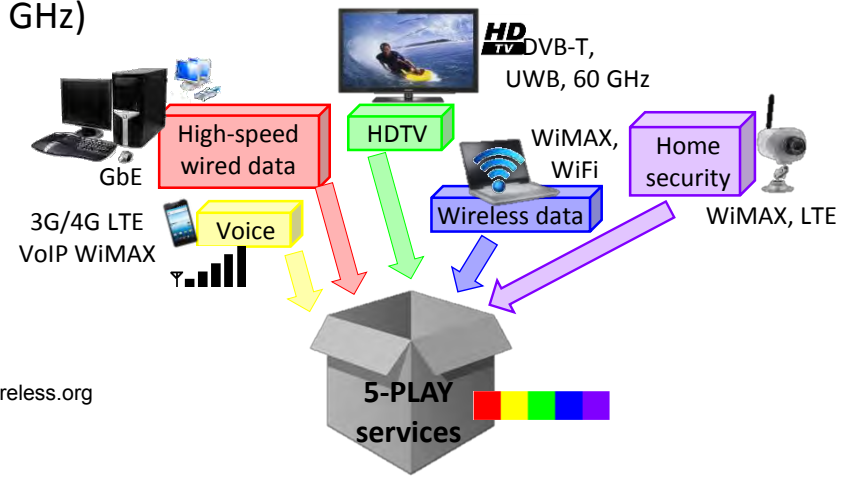
  - Different network services provided **in coexistence**

  Multi-Format Radio-over-Fibre OFDM Bundle

  PSD (a.u.)

  DVB-T · I/Q OFDM · **LTE** · **WiMAX** · **ECMA-368 UWB**

 0,47 · 0.87 · 1.5 · 2.6 · 3.5 · 4.22 · 4.75 · Frequency (GHz)

  - All signals transmitted are **OFDM-based**:
    - DVB-T signals (ETSI EN 300 744) in the UHF band up to 862 MHz for digital TV broadcasting
    - Ad-hoc OFDM signal, between 1 and 2 GHz, to provide features of GbE service
    - LTE (3GPP TS 36.101 Release 8) signal for voice service transmitted in Band E-UTRA 7 with up to 20 MHz bandwidth
    - WiMAX (IEEE 802.16) signal for wireless data transmission, security and domotic services at 3.5 GHz with up to 20 MHz bandwidth
    - UWB (ECMA-368) signals for high-definition audio and video provisioning transmitted in band 2 and 3 of band group 1 (from 3.696 to 4.752 GHz)

HD TV DVB-T, UWB, 60 GHz

High-speed wired data

HDTV

WiMAX, WiFi

Home security

GbE

Wireless data

WiMAX, LTE

3G/4G LTE VoIP WiMAX

Voice

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5-PLAY services

Deep FTTH network with legacy coaxial support

- FIVER optical network integrates the access network and the in-building distribution:
  - Single λ allocated per user in a PON architecture
  - Long-reach access network enabled by OFDM bundle and compensation in place [*]
  - Simple FIVER adapter sub-system for in-building distribution
  - In-building distribution includes:
    - Bend-insensitive single mode fibre (BI-SMF) Corning ClearCurve®
    - "Legacy" coaxial network for DVB-T signals transmission
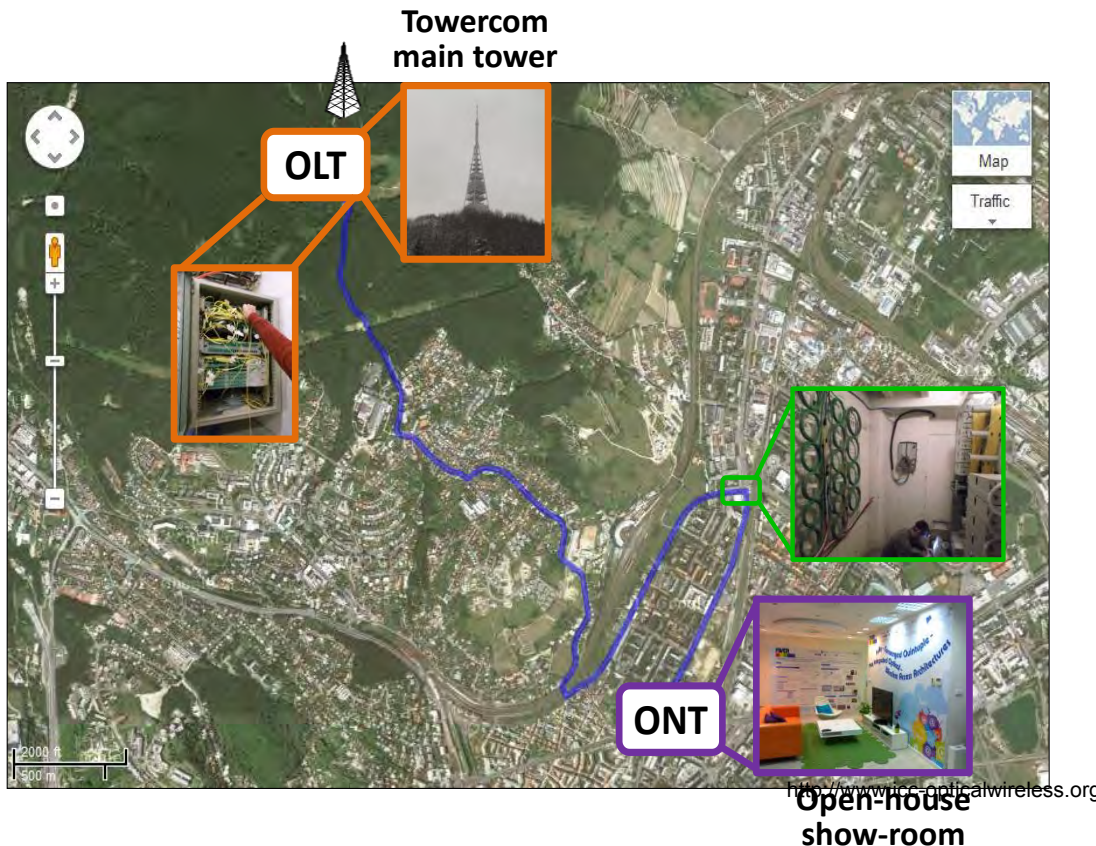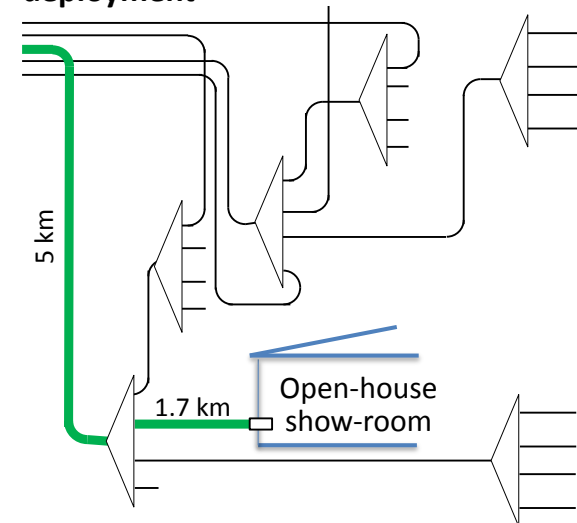

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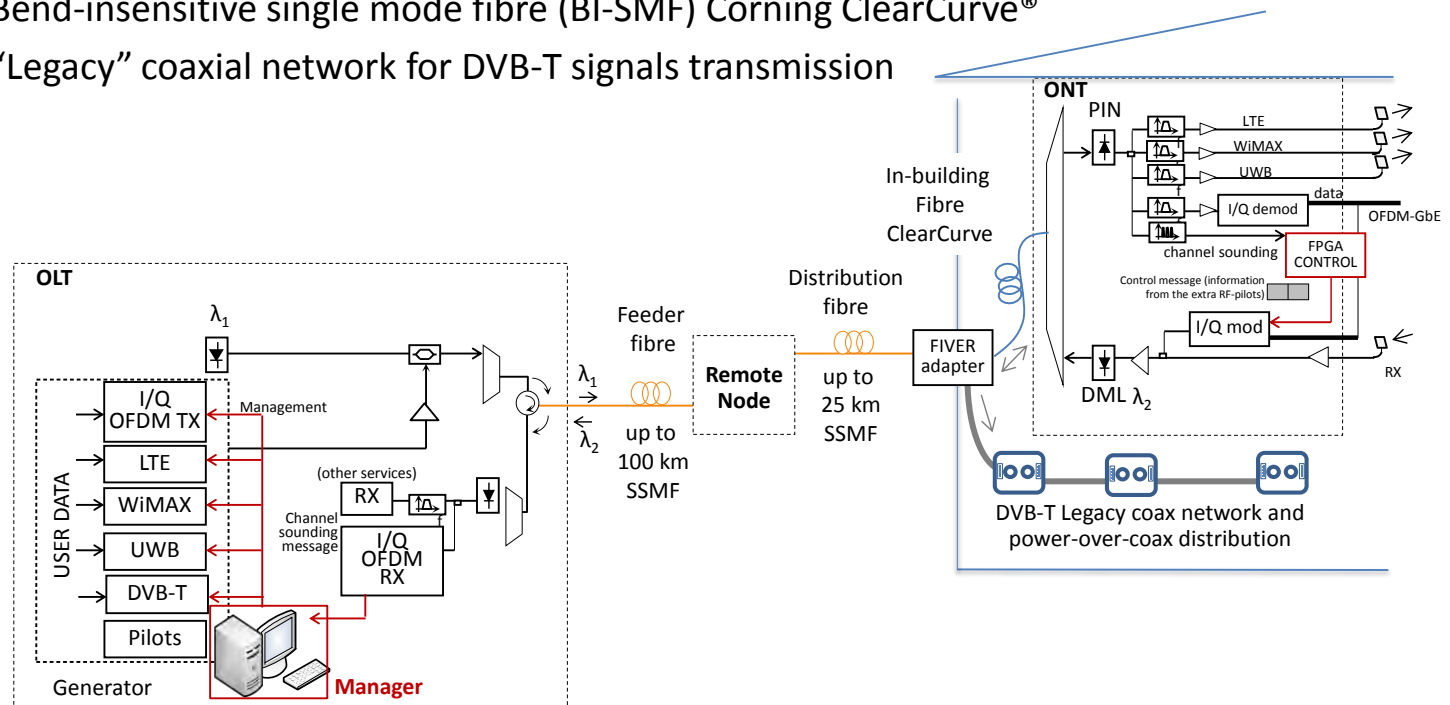
[*] M. Morant, T. Alves, A. Cartaxo, R. Llorente, "Transmission impairment compensation using broadband channel sounding in multi-format OFDM-based long-reach PONs", OFC 2012, paper OW3B.2, March 2012.

Experimental deployment in a real FTTH network

- FIVER network was evaluated in the real FTTH deployment of Towercom operator in Bratislava

  - The open-house demonstrator was installed in a commercial mall in December 2012 at Račianske mýto 1/C, Bratislava

Bratislava city map

Towercom main tower

OLT

ONT

Open-house show-room

http://www.icc-opticalwireless.org

Towercom fibre deployment

5 km

1.7 km

Open-house show-room

Experimental deployment in a real FTTH network

- At the central office (OLT):
  - The quintuple-play services are generated with commercial devices and combined
    - Two neighbor DVB-T channels (ch57 and ch58) generated with Ikusi MAC-401 generators at 762 MHz and 770 MHz, using 8 MHz each with 8k carrier mode in 64-QAM modulation
    - OFDM-GbE generated with an I/Q OFDM modem manufactured by Fibernova Systems
    - A 3GPP LTE signal working in the band of 2.6 GHz
    - A WiMAX signal at 3.5 GHz band using commercial RuggedMAX™ WiN7200 base station
    - A UWB channel working in 528 MHz at 3.96 GHz with Wisair transmitter
  - External Mach-Zehnder modulator (MZ-EOM) working at quadrature bias
  - Multi-user operation combining different wavelengths with an optical multiplexer (MUX)
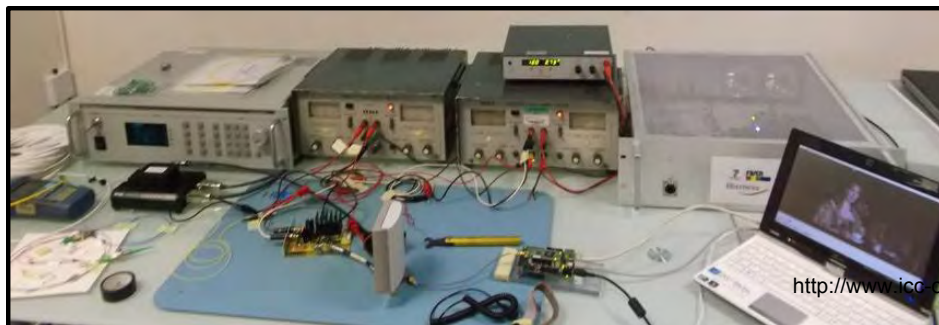 - Downstream and upstream paths are divided using optical circulators

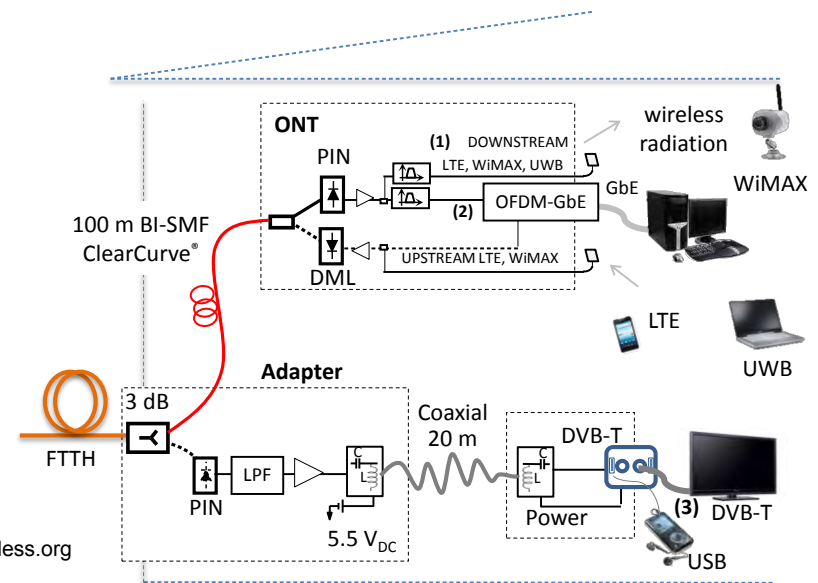Multi-Format Radio-over-Fibre OFDM Bundle
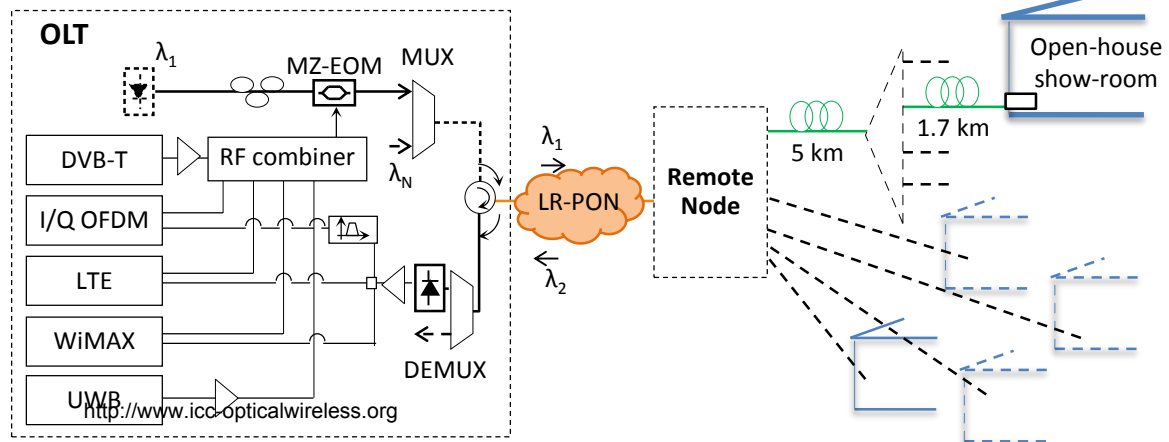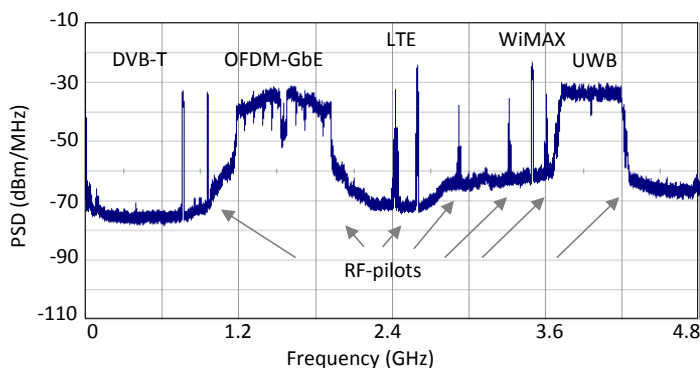
Experimental deployment in a real FTTH network

- After the FTTH transmission, the optical signal is divided in two branches:
    - In-building fiber network using <u>bend-insensitive single mode fiber</u> to receive/radiate the OFDM-GbE, LTE, WiMAX and UWB signals
        - For the upstream a directly modulated laser (DML) is used characterized by threshold I_{th}=8.1 mA and bias I_{bias}=30 mA currents
        - Control information is included in the upstream information of the custom OFDM-GbE, but could be also included in LTE or WiMAX signals as it is transmitted in a TCP packet
    - The DVB-T signals are injected in the <u>legacy coaxial network</u> with simultaneous low-power distribution
        - USB 3.0 devices can be charged directly from the TV plug
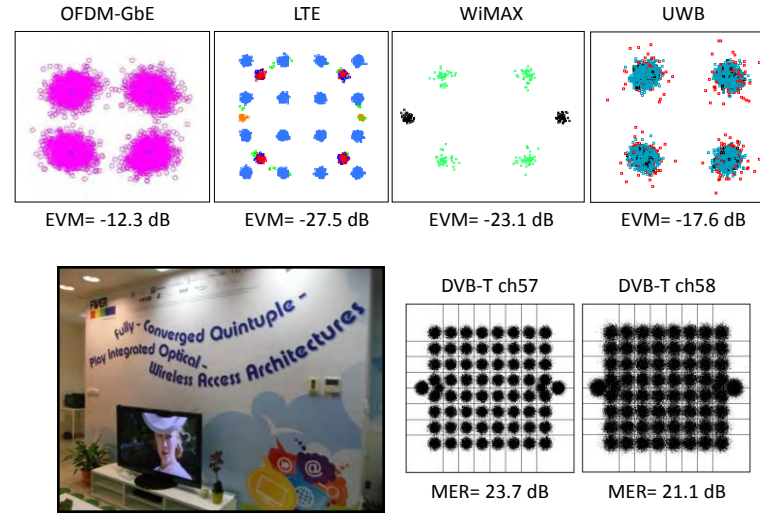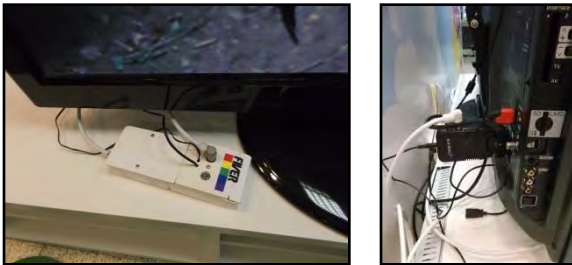
Receiver installed in open-house demonstrator

http://www.icc-opticalwireless.org

Open-house show-room demonstrator

OFDM-GbE · LTE · WiMAX · UWB

EVM= -12.3 dB · EVM= -27.5 dB · EVM= -23.1 dB · EVM= -17.6 dB

- All wireless signals are <u>compliant with the EVM antenna requirements</u> specified in current standards

- Ethernet data is correctly received using the OFDM-GbE signal with $2.6 \cdot 10^{-4}$ bit error rate (BER)

- DVB-T TV channels are correctly received at the TV

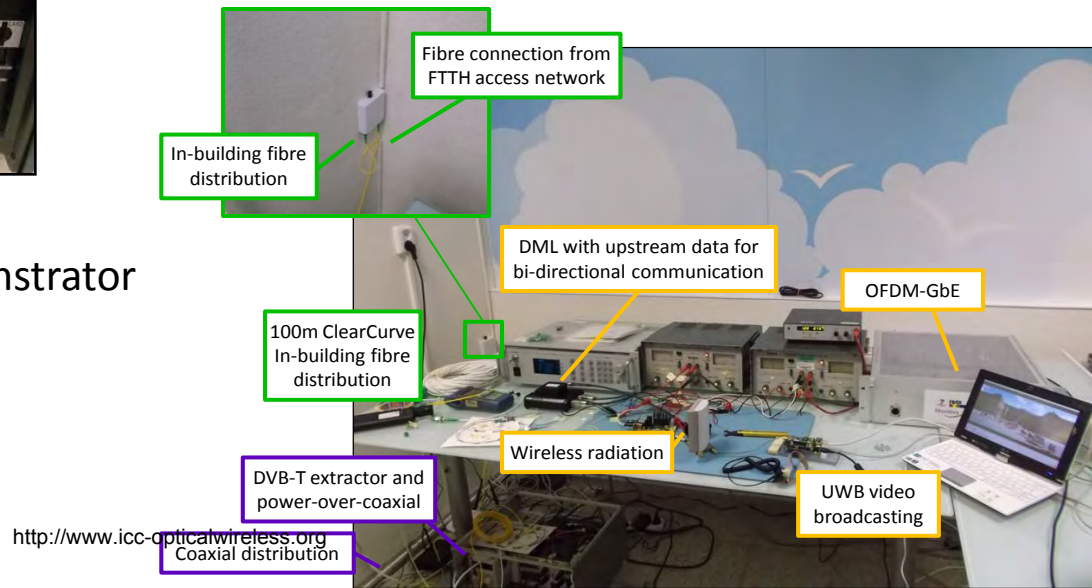- A digital TV receiver is connected to the low-power distribution supply

DVB-T ch57 · DVB-T ch58

MER= 23.7 dB · MER= 21.1 dB

Low-power over coaxial distribution

- A WiMAX security camera was installed in the open-house demonstrator

Security camera

Fibre connection from FTTH access network

In-building fibre distribution

DML with upstream data for bi-directional communication

OFDM-GbE

100m ClearCurve In-building fibre distribution

Wireless radiation

UWB video broadcasting

DVB-T extractor and power-over-coaxial

Coaxial distribution

http://www.icc-opticalwireless.org
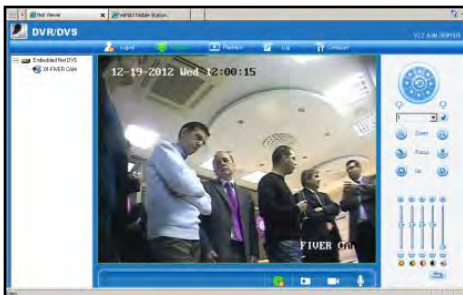
Converged and hybrid 5-PLAY service provision

- This integrated transmission approach permits the **hybrid service provision** of quintuple-play services with the **possibility of receiving the same service over different technologies**

  - This is enabled by the unique centralized radio-over-fibre bundle of signals proposed by FIVER project

Example of video-on-demand received with different technologies

DVB-T

UWB

UWB at 60 GHz

WiMAX

http://www.icc-opticalwireless.org

Centralized management

- Operator control panel for centralized management at the OLT
- Enables the provision of custom pack of contents or each subscriber

Status of the quintuple-play service signals

Received quality of FIVER quintuple-play signals   **Alarms**

Control of the quintuple-play signals:
- Turn on/off each service
- Change centre frequency of each signal OFDM-GbE, LTE, WiMAX, UWB and DVB-T
- Configure the bandwidth of each signal according to current wireless standards
- Change the transmitted power of each signal
- Manage the RF-pilots for channel sounding

Conclusion

- We have demonstrated the converged and hybrid provision of quintuple-play services employing only OFDM-based RoF optical transmission in a deep FTTH network including:

  - Digital television broadcasting with DVB-T signals
  - High-speed data with OFDM-GbE signal
  - Voice service with LTE
  - Wireless data, domotics and security service with WiMAX
  - High-definition audio and video with UWB

- The demonstration was done in a real FTTH network installed in Bratislava including a hands-on demonstration in a open-house show-room

- The attendants to the open-house demonstrator were especially interested in the plug-and-play functionalities of the quintuple-play services using commercial available devices

- Also the attendants liked the possibility of getting the same service using different devices and different technologies

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University of Applied Sciences

CORNING

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EIT+

DAS
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