UPGRADE SCENARIOS FOR FIBER EXTENDED DSL NETWORKS

I. Tsalamanis, M. P. Thakur, J. J. Lepley, S. D. Walker
Optical Systems Research Lab, Department of Electronic Systems Engineering, University of Essex,
Wivenhoe Park, Colchester CO4 3SQ, Tel: +44 (0) 1206 874240, Fax: +44 (0) 1206 872900
itsala@essex.ac.uk, mpthak@essex.ac.uk, jjlepley@essex.ac.uk, stuwal@essex.ac.uk
Structure of the presentation

- Principles of subcarrier multiplexed VDSL channels

- SCM VDSL transmission over several kilometres of SMF
  - Architecture of ONU and OLT
  - Transmission rates and efficiency achieved

- SCM VDSL transmission over cascaded AWG-based network
  - Advantages of arrayed waveguide gratings
  - Upconverted VDSL channels for different band-plans
  - Transmission rates and efficiency achieved

- Conclusions
Subcarrier multiplexed VDSL channels allocation

- Subcarrier multiplexing of VDSL channels
- System bandwidth is divided in smaller windows, each corresponding to a subcarrier
- Each VDSL channel is upconverted at the subcarrier frequency
- VDSL channel upconverted at 16MHz using the China band-plan
- VDSL channel bandwidth depends on the band-plan used
Band-plans tested

- **China band plan 138-8500**
  - 37/30Mbps downstream/upstream per VDSL channel
  - 20MHz bandwidth offering ~25 VDSL channels

- **997-138-8800**
  - 48/35Mbps downstream/upstream per VDSL channel
  - 20MHz bandwidth offering ~25 VDSL channels

- **998-138-17600**
  - 105/50Mbps downstream/upstream per VDSL channel
  - 40MHz bandwidth offering ~12 VDSL channels
Optical VDSL transmission over 20km SMF

CP

CPE modem
100BASE-T
106m UTP

ONU

DFB-LD
LO
Photodiode
Directional Coupler

EDFA

UPSTREAM

OLT/CO

DFB-LD
EDFA
Photodiode
Directional Coupler

互联网

INTERNET

DSLAM
Distribution point upstream multiplexer

- 106m UTP cable between CPE modem and ONU
- Upstream and downstream signals are split by a direction coupler
  - Coupler consists of lossless differential balanced op-amps
  - Frequency independent
- Differential to common-mode conversion
- High-pass filter remove the residual wristband signal that results from imperfect conversion
- VDSL signal is upconverted to the corresponding subcarrier
- All VDSL signal are combined before direct modulate the laser
Central Office OLT

- Optical Line Termination unit has similar architecture with ONU
- PIN photodiode detects the optical signal
- Upconverted VDSL channels are split
- Downconverted and driven to modem
- Circulators are used to achieve bidirectional traffic
Transmission rates for different fibre lengths

- Average downstream/upstream 46.4/24.1Mbps for fast-998 (67/40) bandplan baseline transmission
- 36.7/24Mbps for fast-998 (67/40) bandplan 20km SMF transmission
- 28.5/11Mbps for fast-998 (67/40) bandplan 45km SMF transmission
Transmission efficiency for fast-998 bandplan

- **Electrical baseline (baseband):**
  65/39Mbps resulting in 97% and 97.5% downstream and upstream efficiency, respectively

- **Electrical baseline (upconverted):**
  46.4/24.1Mbps resulting in 69% and 60% efficiency

- **Optical baseline:**
  40/24Mbps resulting in 60% and 60% efficiency

- **20km NZDSF:**
  36.7/24Mbps resulting in 55% and 60% efficiency

- **45km NZDSF:**
  28.5/11Mbps resulting in 42.5% and 27.5% efficiency
VDSL transmission over cascaded AWG-based network

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106m UTP

Upstream
Downstream

20km Optical fibre

1x16 AWG

OLT/CO

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DSLAM
Arrayed Waveguide Gratings

- NxN arrayed waveguide gratings (AWG)
- Passive optical routers
- Constant channel spacing (25, 50, 100 or 200GHz)
- Low insertion loss (for 1xN = 3-5dB, for NxN = 8-12dB)
- Latin routing characteristics
  - Cyclic allocation of the same wavelengths at the output ports
  - Coverage of all wavelength bands
- Bidirectional transmission following the same optical path
- Network can address a large number of users depending on the number of ports of the NxN AWG, the number of wavelengths used and the number of VDSL channels modulated on each wavelength
  - 12288 users when 24 VDSL channels, 32 wavelengths and 16x16AWG are used
Upconverted VDSL channels

- Upconverted channels at 50MHz and 120MHz using the China band-plan
- 8.5MHz and 17MHz bandwidth for downstream and upstream channels, respectively
- More than 15dB SNR was achieved
- Third harmonics are at least 15dB below the signal spectrum

- Upconverted channel at 250MHz using the 998 band-plan
- More than 30dB SNR was achieved
12 bits can be allocated on back-to-back connection

4 maximum bits were allocated to the tones for the hybrid copper/optical network

For China band-plan (37/30) 15.7/13.8Mbps were achieved, thus 42% and 46% efficiency for downstream and upstream

For 998 band-plan (67/40) 36.2/22Mbps were achieved, thus 54% and 55% efficiency for downstream and upstream

Triple play (video, sound and data transmission) was achieved with no packet or frame losses
Conclusions

- Upgrade scenarios for legacy copper network services were assessed
- Subcarrier multiplexing of VDSL channels offers an inexpensive upgrade to fibre extended xDSL networks
- 36.7/24Mbps and 28.5/11Mbps were achieved for 20km and 45km of SMF, respectively, using fast-998 (67/40) bandplan
- Transmission efficiency of 55% for downstream and 60% for upstream in the 20km case and 42.5% and 27.5% in the 45km case
- Subcarrier multiplexing was applied in a cascaded AWG-based network
- 12288 users can be addressed when 24 VDSL channels, 32 wavelengths and 16x16 AWG are used.
- 36.2/22Mbps were achieved, thus 54% and 55% efficiency for downstream and upstream, when 998 band-plan is used