THE FUTURE OF COPPER

Jochen Maes, Broadband Innovation, Bell Labs Alcatel-Lucent
G.fast summit, Paris, May 2014
FTTH
THE NEXT BIG THING SINCE DECADES

FIBER TO THE HOME: PRACTICALLY A REALITY

John Bourne
BNR

1988

INSTALLED FIRST COST ECONOMICS OF FIBER/BROADBAND ACCESS TO THE HOME

K. Lu, R. Wolff and F. Gratzer

Bell Communications Research
445 South Street, Morristown, NJ 07960

1988

... It shows that fiber will be cost competitive for voice during the 1990's and predicts that Broadband access will become cost effective during the next 10 to 15 years ... 


Camille VeYres (x) -- J. Jacques Mauro

Direction Générale des Télécommunications
France Telecom - Service des Télécommunications
de l'Image - Paris - France

1988

An Optimal Investment Strategy Model for Fiber to the Home

Marvin A. Sirbu and David P. Reed

Carnegie Mellon University

1988

Optical fibers reach into homes

Paul W. Shumate Jr. Bell Communications Research Inc.

1989

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THE REALITY
GRADUAL FIBER DEPLOYMENT

CO deployment ➔ FTTCab

CO
passive cross-connect cabinet

CO
mini DSLAM
WE’VE SOLVED THE BANDWIDTH EQUATION

COST

FTTH

FTTN / VDSL2

1 MBPS 10 MBPS 100 MBPS 1 GBPS
DRIVERS FOR BANDWIDTH

Applications

Competition

Regional incentives
ACCESS NETWORKS AROUND THE GLOBE CONTINUOUSLY NEED TO TRANSFORM TO KEEP UP WITH BANDWIDTH DEMANDS

- **EU Digital Agenda**: 30M for all, 100M for 50% by 2020
- **China 12th 5-year plan**: FTTH (CT: 100M for 100M by 2015)
- **Connected America**: FCC National BB plan, 100M for 100M by 2020
- **India National Backbone**: Broadband for 90% by 2013
- **Brasil Plano Nacional**: 100M for 90% by 2020
- **Australia NBN**: 100M for 90% by 2020
- **New Zealand UFB**: 100M for 75% by 2020
WE’VE SOLVED THE BANDWIDTH EQUATION

- FTTN / VDSL2
- FTTx VDSL2 VECTORING
- FTTx G.FAST

COST

1 MBPS 10 MBPS 100 MBPS 1 GBPS
THE REALITY
GRADUAL FIBER DEPLOYMENT CONTINUES

CO deployment ➔ FTTCab ➔ FTTdp

CO deployment

FTTCab

FTTdp

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VDSL2 VECTORING CONCEPT

COPPER PAIRS INTERFERE WITH EACH OTHER, REDUCING BITRATES

VECTORING = NOISE CANCELLATION HEADPHONES FOR YOUR COPPER PLANT
MAKING VECTORING EASY TO DEPLOY

EASY MIGRATION
- Zero-touch Vectoring: no need to firmware-upgrade legacy VDSL2 CPE
- Unique Alcatel-Lucent solution
- Re-use existing nodes

HIGH SCALABILITY
- System-Level Vectoring versus SEMs
- Bonding+Vectoring for increased reach/rate

EFFICIENT OPERATIONS
- Vectoring support in Motive Network Analyzer
- Cross-talk mapping
- SELT / DELT / MELT for Vectoring
5530 NETWORK ANALYZER
COMPLETE COPPER & FIBER SOLUTION

- Pre-qualify copper lines
- Upgrade Prediction for ADSL2+, VDSL2, Vectoring
- Vectoring activation tools
- Fiber activation tools

TROUBLESHOOTING
- Copper Line Diagnosis (using DELT / SELT / DSL stats / NBLT)
- DSL Binder/Bonding/Vectoring group diagnosis
- Fiber / GPON fault diagnosis (detect and localize)

PROACTIVE MANAGEMENT & OPTIMIZATION
- Continuous DSL monitoring and QoS classification
- Dynamic Line Management (DLM)
- Proactive DSL fault diagnosis
- Continuous GPON monitoring and QoS classification
- Proactive Fiber / GPON fault diagnosis
ACCESS NETWORK SOLUTIONS
USER EXAMPLES
FTTDP ARCHITECTURE

1 to 48 users per remote network equipment

(X)GPON, P2P, copper backhaul BBF project FTTdp

Aggregation

Passive splitter

DPU

CPE

ITU-T

150 Mb/s vectored VDSL2 17a
(250 Mb/s with 30a)
1 Gb/s G.fast

DPU can be powered from the customer premises
ETSI TM6 101548 CPE powered network equipment

G.fast transceiver
Power extraction
DPU power supply unit

Power insertion
Power source
G.fast transceiver

60 Vdc

DPU
FTTDP EQUIPMENT

Small
Energy efficient
Water tight
TYPICAL APPLICATIONS FOR G.FAST & G.FAST VECTORING

- **FTT...**
  - NODE
    - >200 METER
    - >100 SUBS
    - VDSL2 VECTORING

- **Curb**
  - <200 METER
  - 10s OF SUBS
  - VDSL2 VECTORING
  - EVOLUTION TO G.FAST VECTORING

- **Manhole**
  - a.k.a. “FTTdp”
    - (Distribution Point)

- **Pole**
  - 10s OF METERS
  - 1 SUB
  - VDSL2
  - EVOLUTION TO G.FAST

- **Building**

- **Wall**

- **Front Door**

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GIGABIT SPEEDS WITH G.FAST

1. **MORE BANDWIDTH**
   - G.fast: up to 106 MHz (212 MHz in future)
   - Limitation on bits/s/Hz to manage design complexity

2. **SHORT DISTANCE**
   - To reduce attenuation at high frequencies

3. **HIGH BITRATES**
   - Standard targets:
     - 150Mbps @ 250m
     - 200Mbps @ 200m
     - 500Mbps @ 100m
     - Up to 1Gbps <100m

\[ C = \eta W \log_2 \left(1 + \frac{|H|^2 P_t}{\Gamma (\sigma_0^2 + I)} \right) \]
EASE OF INSTALLATION

**Easy deployment**
- DPU install-and-forget
- Remotely managed
- Managed when unpowered

**Customer self-install**
- Robust performance on existing in-home wiring (bridged taps)
- Reduced rate compared to technician install

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30% of FTTH subscribers change their mind when the engineer asks where he can drill holes in the wall for the fiber

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Different powering options

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REVERSE POWERING CHALLENGES

\[ P_{CF} = \text{power consumption common functionality} \]
\[ P_{LS} = \text{line specific power consumption} \]

High end: power consumption with all lines active is limited by thermal dissipation constraints

P_{CF} \quad \begin{array}{c} \text{power consumption as function of # active lines} \\ \text{power that can be delivered with reverse powering} \end{array} \quad \begin{array}{c} \text{Optimal available power (reverse feeding)} \\ \text{Optimal available power (forwards feeding)} \end{array}

Low end: single line should be able to power common part + 1 line specific part

For reverse powering most challenging situation is first user powering DPU
REVERSE POWER FEED FRAMEWORK

DPU accommodates Interaction MELT-RPF

Voice delivery: many options

In-Home telephone wiring (e.g. without central point)

G.Fast

+Voice

POWER +

signaling

DPU management

Optional Battery (lifeline) incl. OAM

Self-install by user

Legacy service

non-conforming device

POWER SOURCE (PSE)

FTTdp BB service

multi-line RPF extraction including communication with PSE, line fairness, bypass switching, ...

RPF injection incl. communication with DPU and detection of non-conforming device
G.FAST DPU MANAGEMENT, PON UPLINK TR-156 BASED INTEROPERABLE APPROACH

Simplification: no OMCI standardization of xDSL provisioning required
Requires OMCI standardization of Performance Monitoring and status portion of xDSL MIB
Ensures IP safety & scalability: Only 1 IP address needed per OLT (no IP in DPU)
Persistent Management Agent can be integrated in existing platform (OLT EMS or OLT)
DPU Config file generator can be integrated on some IT infrastructure
(does not require DPU vendor’s EMS)
Alarms and Performance Monitoring are OMCI based and correlated in OLT

management entities involved
CO-EXISTENCE

Ingress/egress control
- Can notch any band
- No egress noticed so far

Upgrade scenario
- Start above VDSL2 for co-existence
- Use full 2.2-106 MHz spectrum once all VDSL2 users migrated

FLEXIBLE NOTCHING CAPABILITIES FOR COMPATIBILITY WITH LEGACY SERVICES
VERSATILE

Flexible DS:US ratio
- Mandatory 30:70 to 90:10
- Optional 10:90 to 30:70

Mobile backhaul
- Low latency framing option
- Network Timing Reference and Time of Day

Scalable power consumption
- Proportional to traffic load
- Autonomous or managed
- Ultra-low power for VoIP support

Not just twisted pair
- Alcatel-Lucent proven performance over cable
- For point-to-point coax topologies
G.FAST USES TIME DIVISION DUPLEXING

1 TDD frame ≈ 750 µs

Normal operation interval (NOI)
- length TTR, common to all lines

Discontinuous operation interval (DOI)
- combination of quiet periods and transmission opportunities
- Configured per line

NOI and DOI configured by DRA (Dynamic Resource Allocation)
USE CASES FOR NORMAL AND DISCONTINUOUS OPERATION

Minimum number of DMT symbols required:

DRA control, example 1: full vectored in NOI, off in DOI

Lost energy saving potential
Idle symbols
USE CASES FOR NORMAL AND DISCONTINUOUS OPERATION

Minimum number of DMT symbols required:

DRA control, example 2: full vectored in NOI, reduced vectored group in DOI

Lost energy saving potential
Active symbols
USE CASES FOR NORMAL AND DISCONTINUOUS OPERATION

Minimum number of DMT symbols required:

DRA control, example 3: full vectored in NOI, TDMA in DOI
VECTOR 2.0

The numbers are in
• Trials show huge impact of crosstalk
• And huge benefit of Vector 2.0
• High variability in cable quality, both single user and crosstalk

Rate/reach
• G.fast cable model (CAD55)
• One 99% worst case crosstalk
VECTORING IN G.FAST

Gain Scaled Linear Precoding

Pre-compensation

Nonlinear Precoding

Modulo operation reduces transmit power

Higher bitloading with nonlinear precoding.

Received power (dBm/Hz)

Direct signal

Crosstalk signal

Noise

0 17.7 MHz 212 MHz
VDSL2 G.fast

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G.fast technologically feasible – analog will be limiting design factor

Note: Similar results for memory requirements. But analog complexity does not obey Moore’s Law
DSL DATA RATES HAVE BEEN CONSISTENTLY INCREASING OVER THE LAST TWO DECADES
VERY HIGH SPEEDS, VERY SHORT DISTANCES

- Hundreds of Mbps at very short distances
- 1Gbps+ at tens of meters
- Fiber “nearly” to the home
- Designed for self-install & any type of wiring

COMPLEMENTS FTTH AND VDSL2 VECTORING

- G.Fast can accelerate FTTH deployments
- Promising evolution for short-loop FTTx models
- VDSL2 vectoring for loops exceeding 200m

TECHNOLOGY STILL EVOLVING

- Ratified standard 2014
- Chipsets 2015, products earliest 2016
- Challenges remain: need for vectoring, power management, etc.

BUSINESS CASE VARIES PER OPERATOR

- The closer to the end-user, the higher the cost
- ... but avoid entering the home (costly & time-consuming)