TRENDS IN HYBRID FIBER-COPPER ACCESS NETWORKS

Jochen Maes, Broadband Innovation, Bell Labs Alcatel-Lucent

Keynote @ IEEE Globecom Standards Workshop, 2014

Alcatel·Lucent

FTTH
THE NEXT BIG THING SINCE DECADES

Optical fibers reach into homes 1989

Paul W. Shumate Jr. Bell Communications Research Inc.

FIBER TO THE HOME: PRACTICALLY A REALITY

John Bourne 1988

BNR

An Optimal Investment Strategy Model for Fiber to the Home

Marvin A. Sirbu and David P. Reed 1988

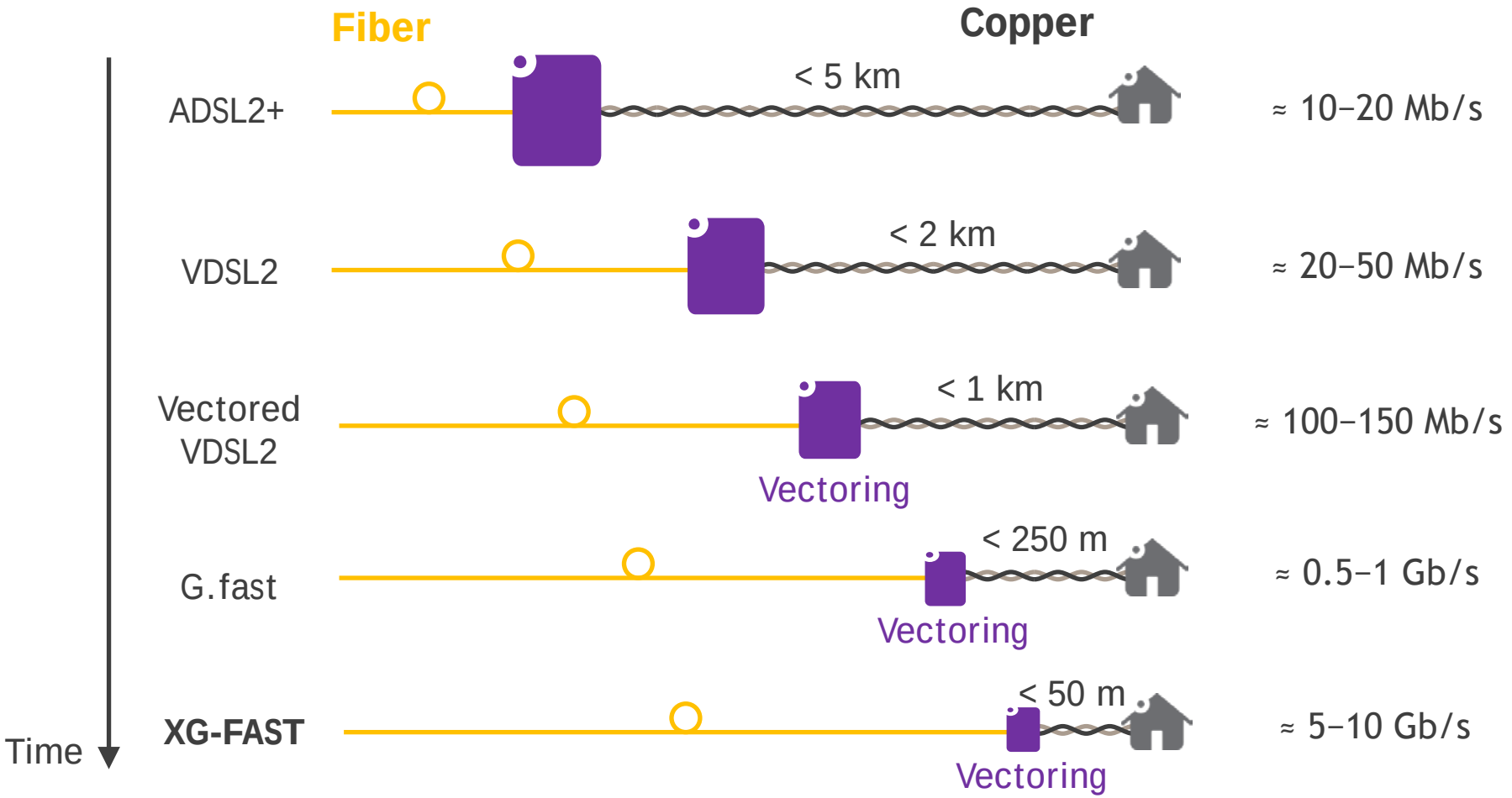
Carnegie Mellon University

Delays and unexpected cost increase due to

- Difficulties in mobilizing a large workforce
- Delays in finalizing agreements among parties involved
- Network turned out less fiber-ready than expected

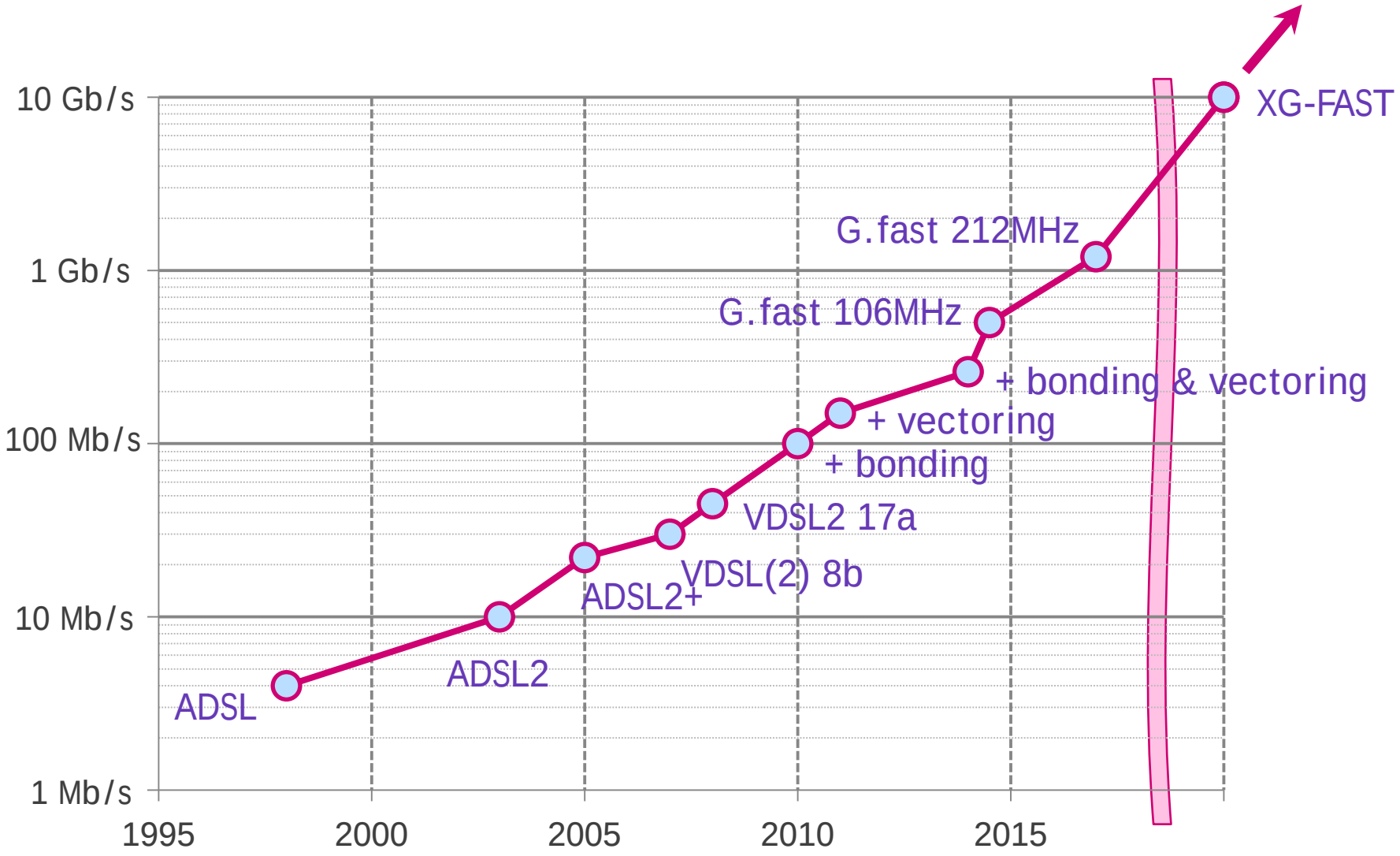
Kudelka

REALITY: GRADUAL EXPANSION OF THE FIBER NETWORK



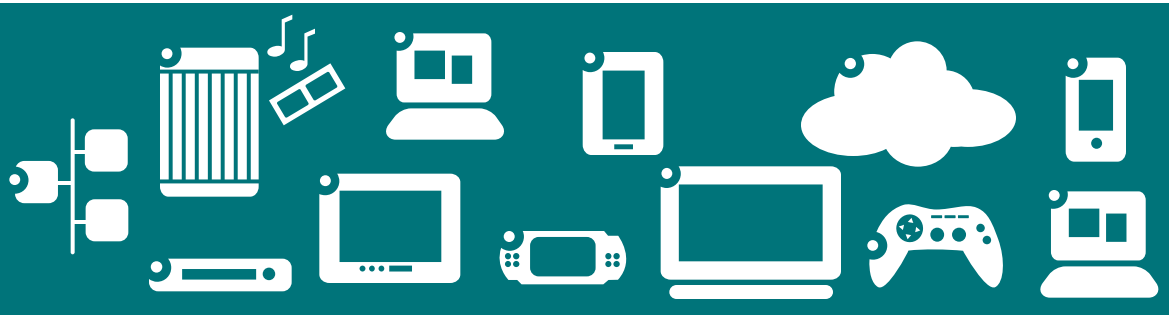
Leverage legacy network for rapid nation-wide service upgrades

BROADBAND OVER A HYBRID FIBER-COPPER NETWORK



DRIVERS FOR BANDWIDTH

Applications



Competition

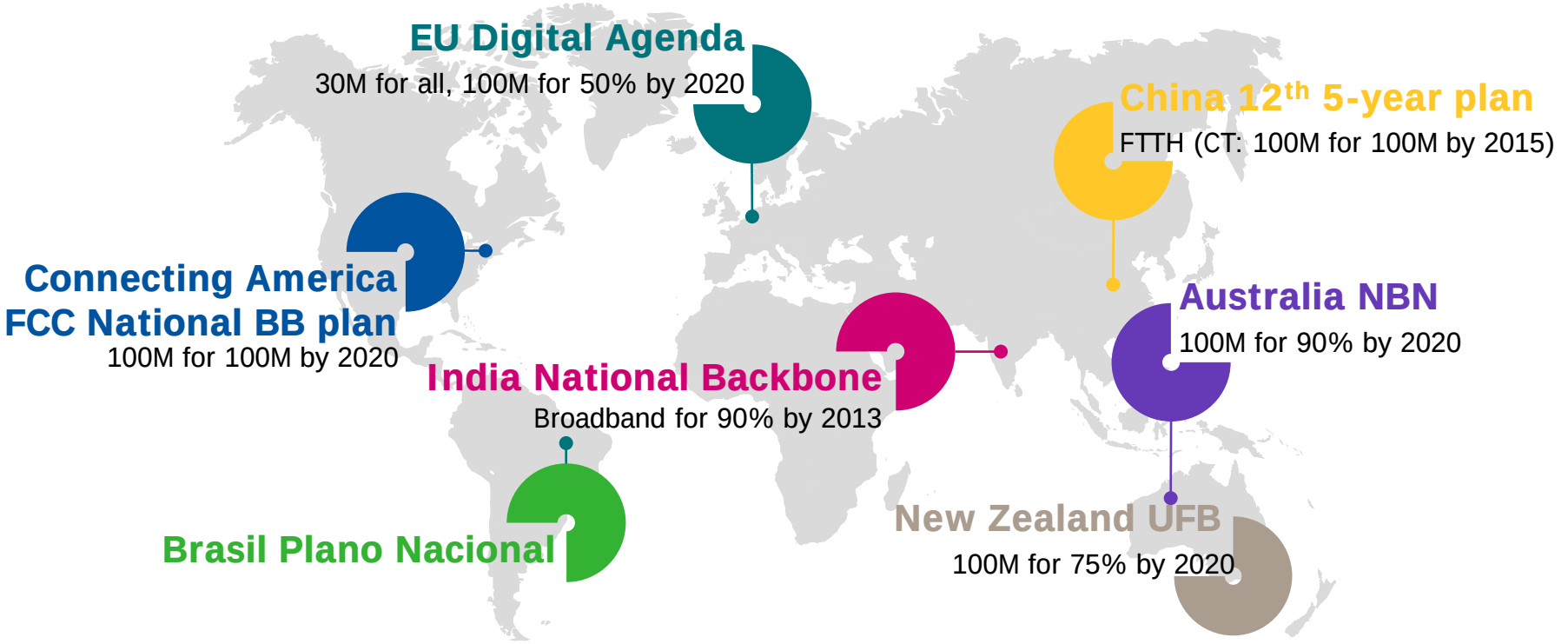
Regional incentives

EUROPEAN COMMISSION

FEDERAL COMMUNICATIONS COMMISSION · USA ·

NBNCo Limited

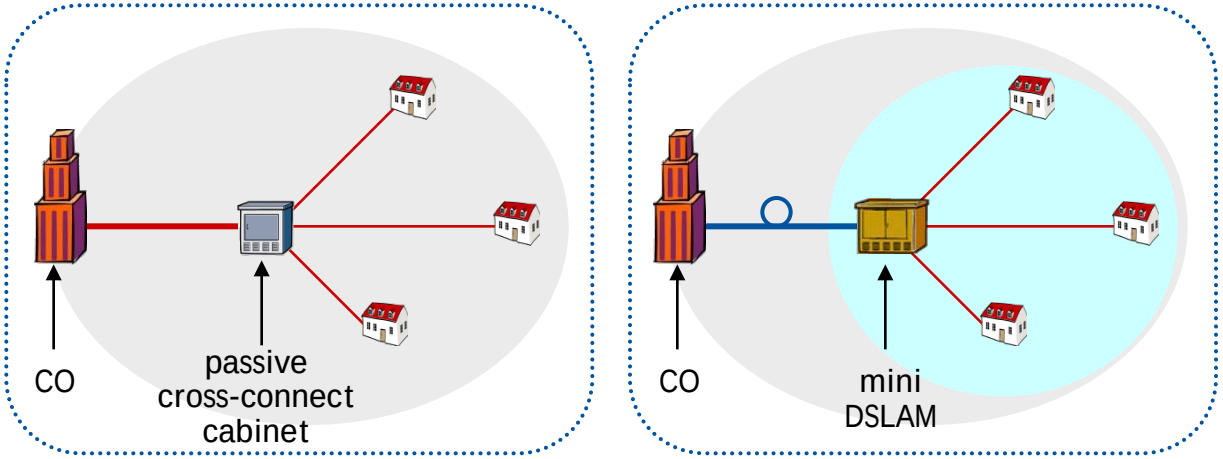
ACCESS NETWORKS AROUND THE GLOBE CONTINUOUSLY NEED TO TRANSFORM TO KEEP UP WITH BANDWIDTH DEMANDS



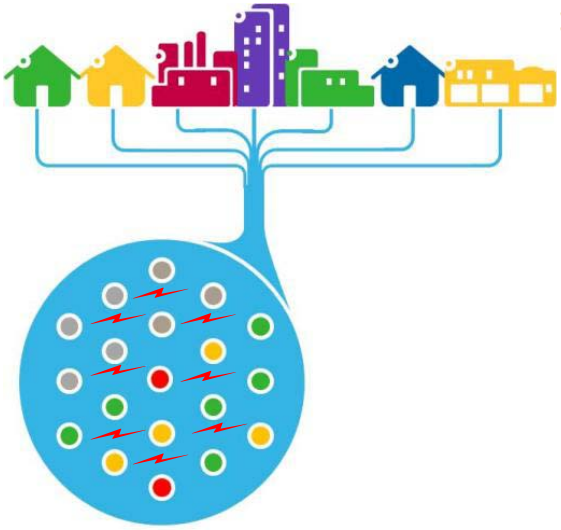
100 Mb/s tier driven by national incentives

GRADUAL FIBER DEPLOYMENT

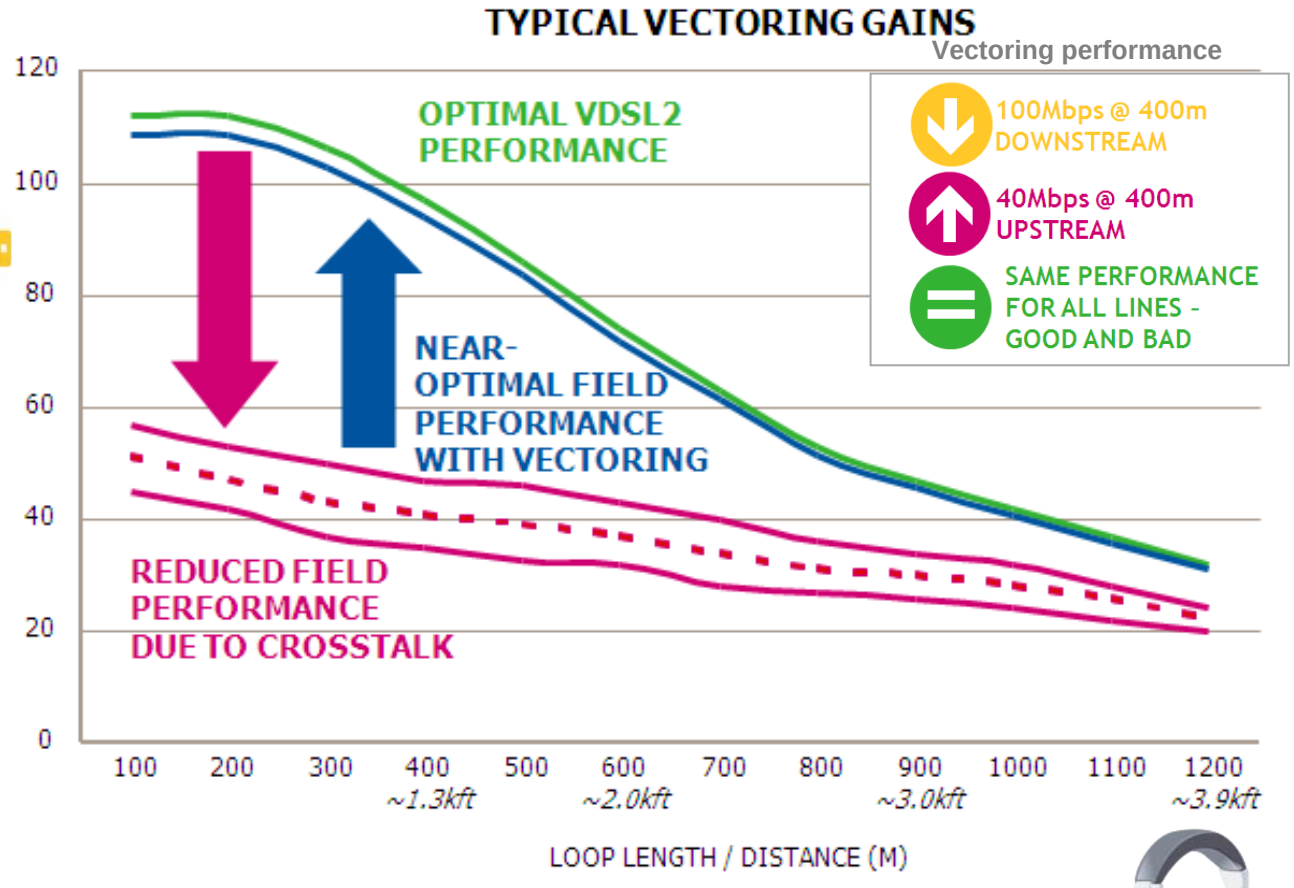
CO deployment → **FTTCab**



VDSL2 VECTORING CONCEPT

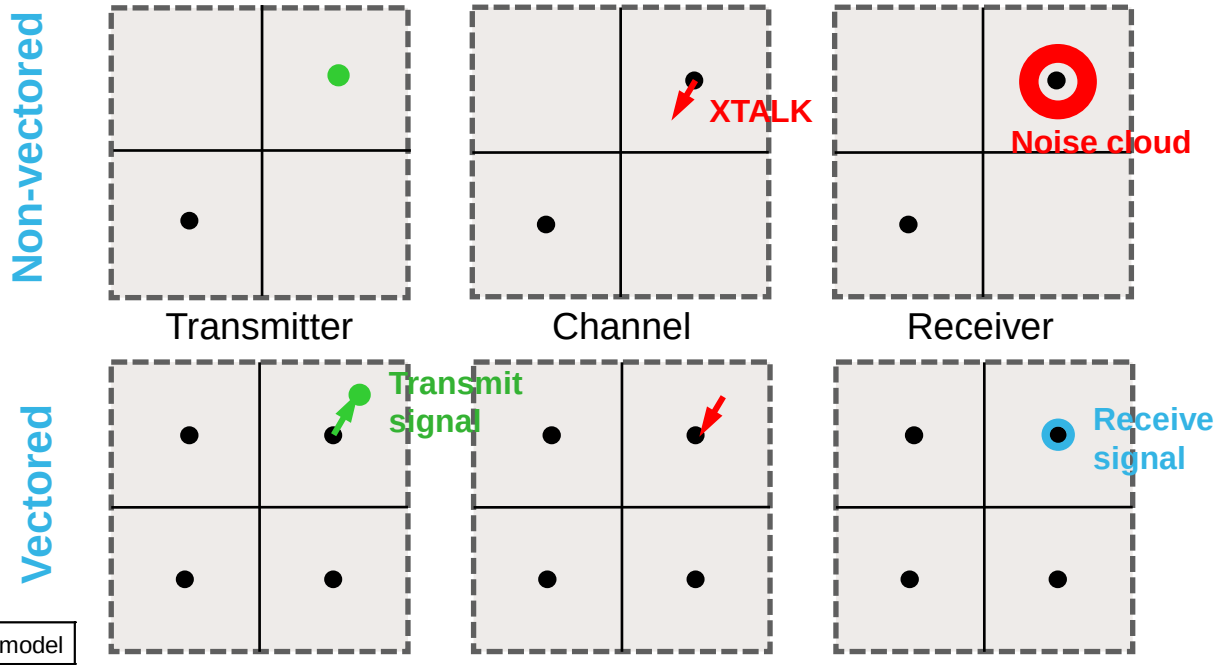


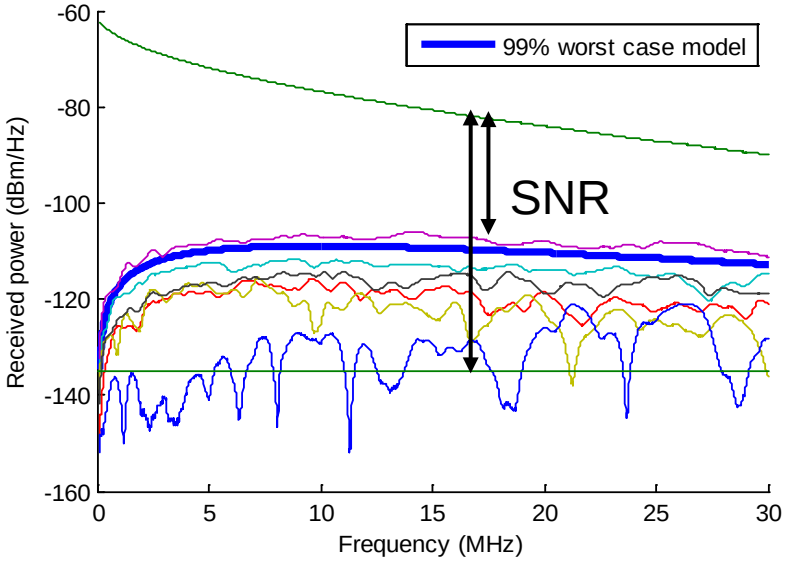
COPPER PAIRS INTERFERE WITH EACH OTHER, REDUCING BITRATES



Vectoring = noise cancellation headphones for your copper plant

G.VECTOR: CROSS-WHISPERING

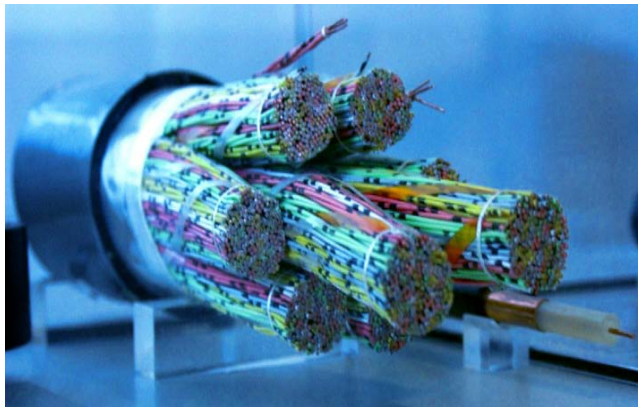




Received signal

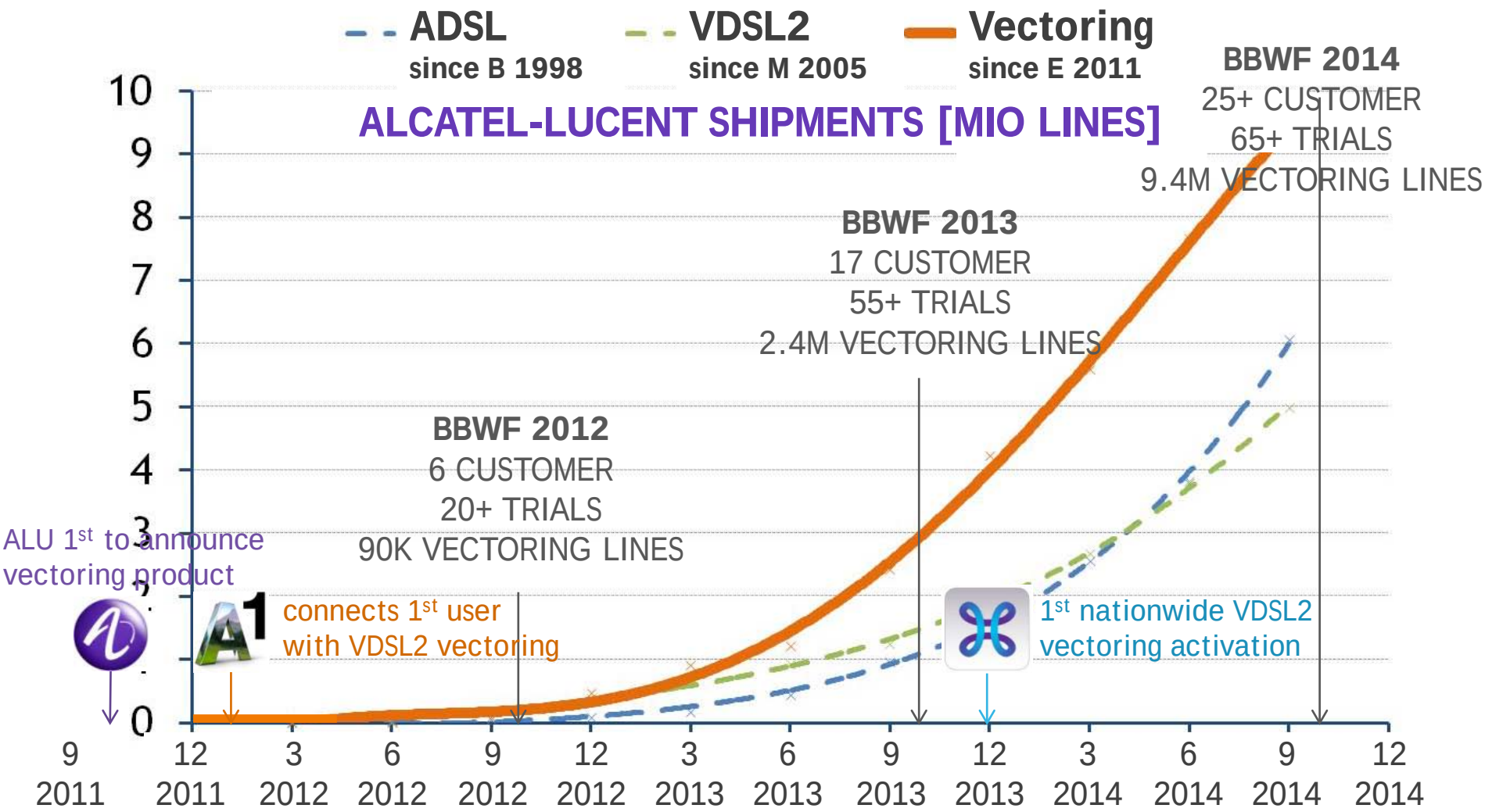
Received crosstalk

Modem noise floor



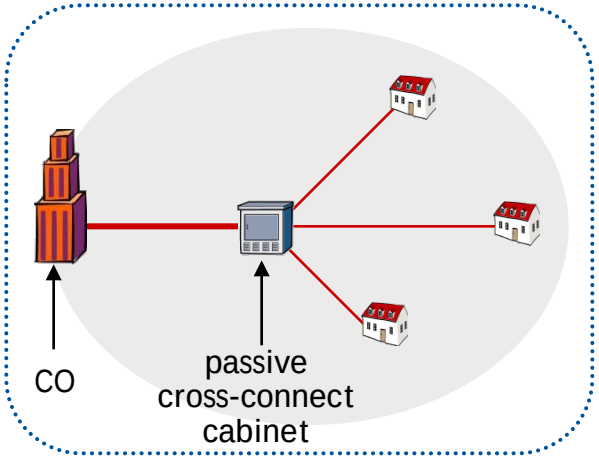
VECTORING IS ON THE RISE

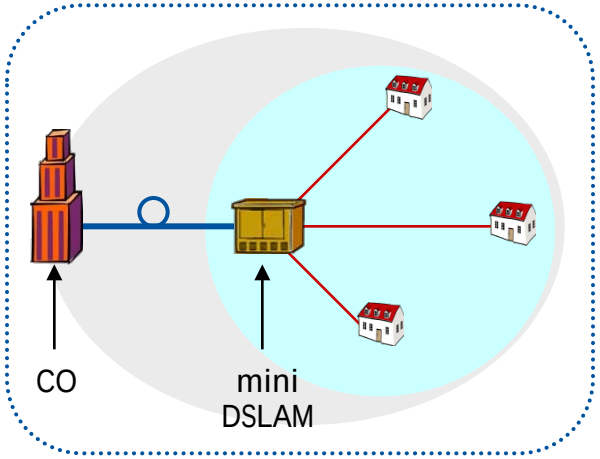
HELPS OPERATORS GET MORE FROM THEIR DSL COPPER NETWORKS

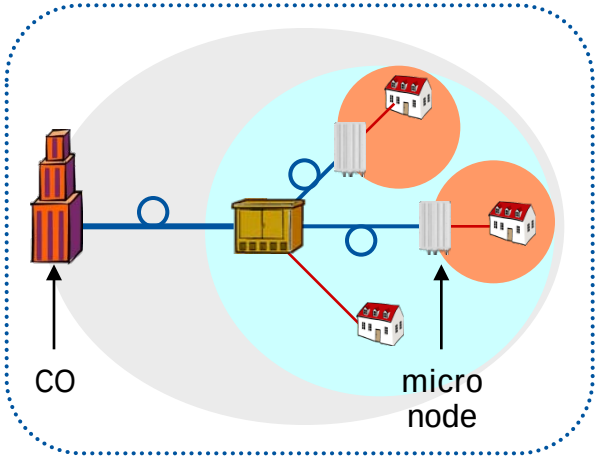


GRADUAL FIBER DEPLOYMENT CONTINUES

CO deployment → **FTTCab** → **FTTdp**

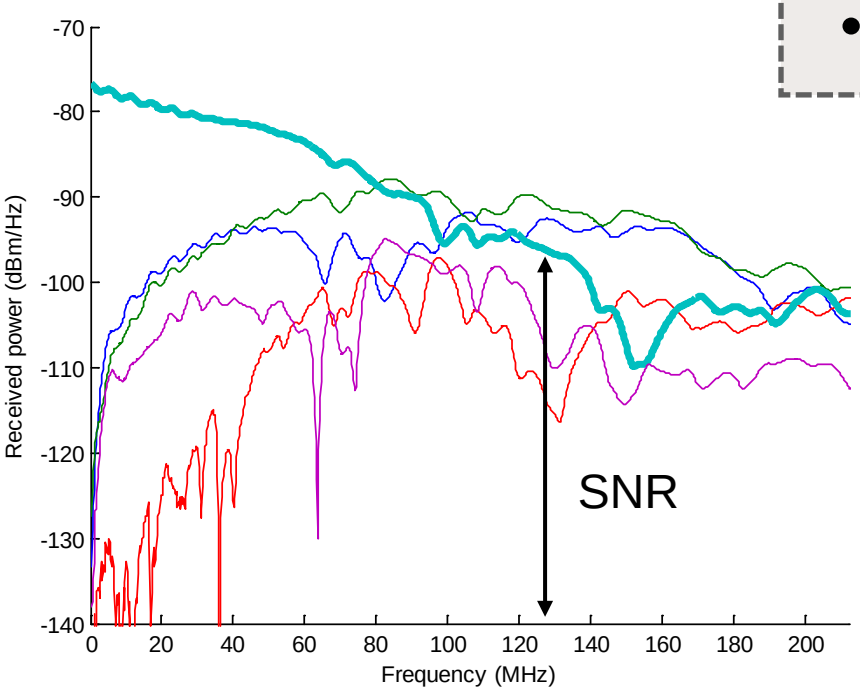


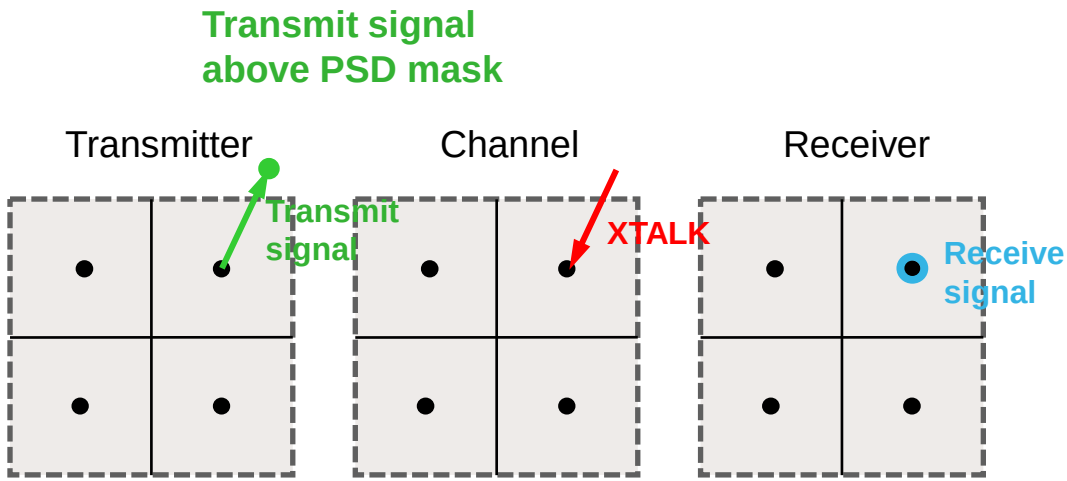




G.FAST: CROSS-SHOUTING

- Channel no longer diagonally dominant
- Power constraints must be met
- Alternatives to linear zero-forcing become interesting





Transmit signal | Precoder | User signal

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix}$$

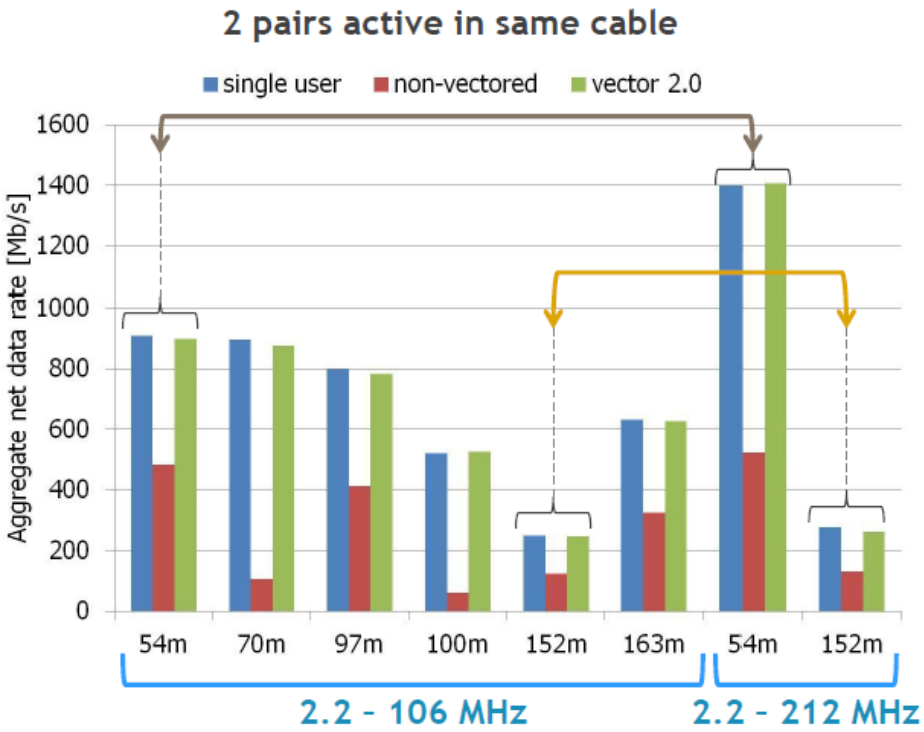
Power on line

Power of user signal

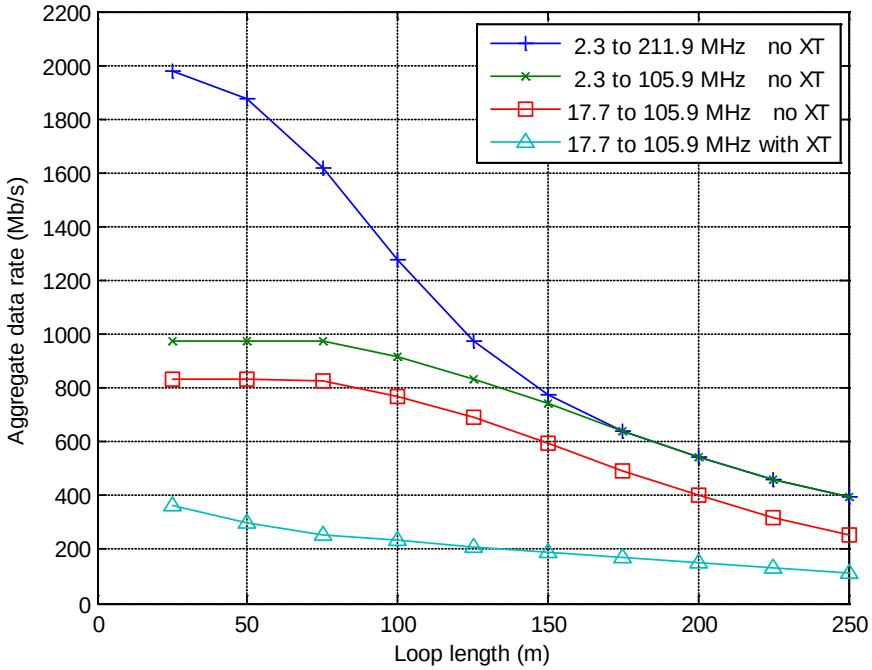
M. Guenach, et al., IEEE Globecom 2014

VECTOR 2.0

MEASURED



SIMULATED



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

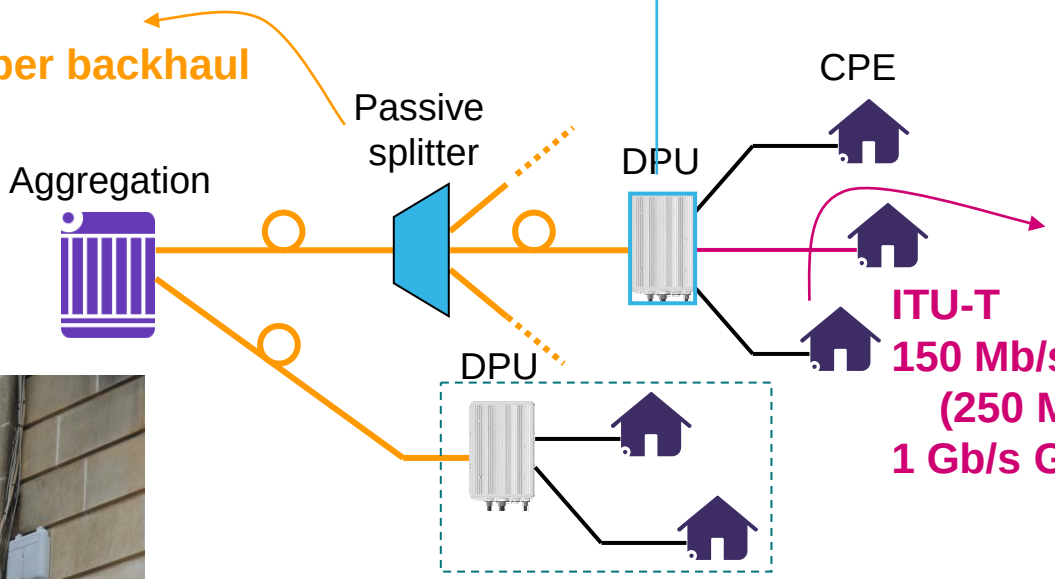
Rate/reach

- G.fast cable model (CAD55)
- One 99% worst case crosstalker

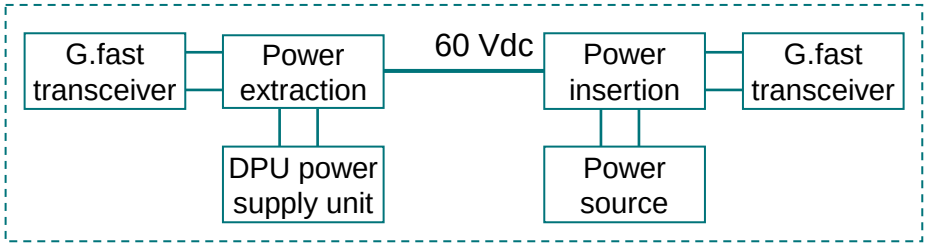
FTTDP ARCHITECTURE

1 to 48 users per remote network equipment

(X)GPON, P2P, copper backhaul
BBF WT-301 FTTdp

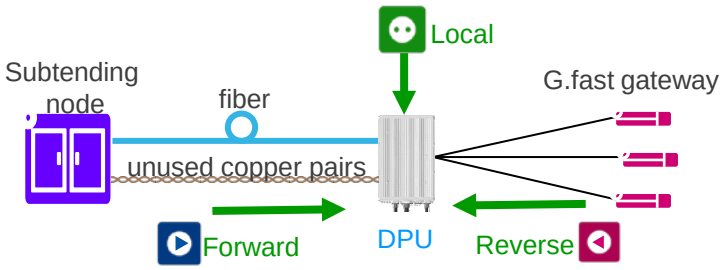


ITU-T
150 Mb/s vectored VDSL2 17a
(250 Mb/s with 30a)
1 Gb/s G.fast



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

REVERSE POWERING

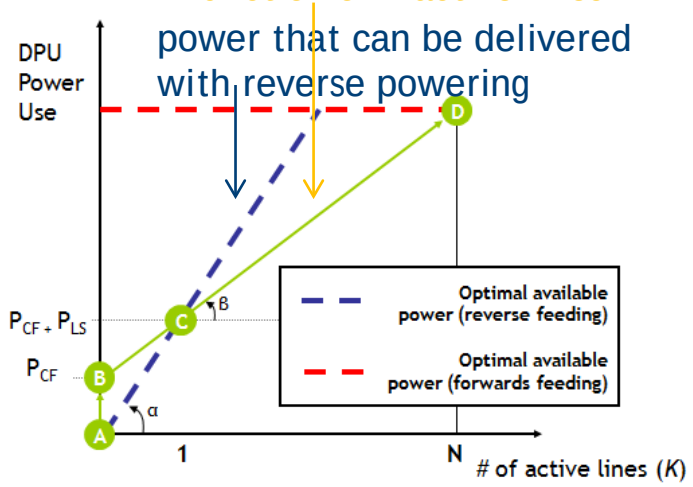


power consumption as function of # active lines

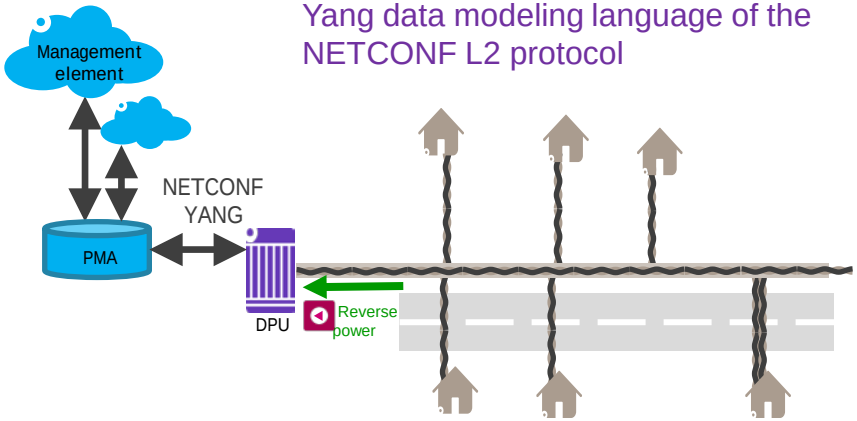
power that can be delivered with reverse powering

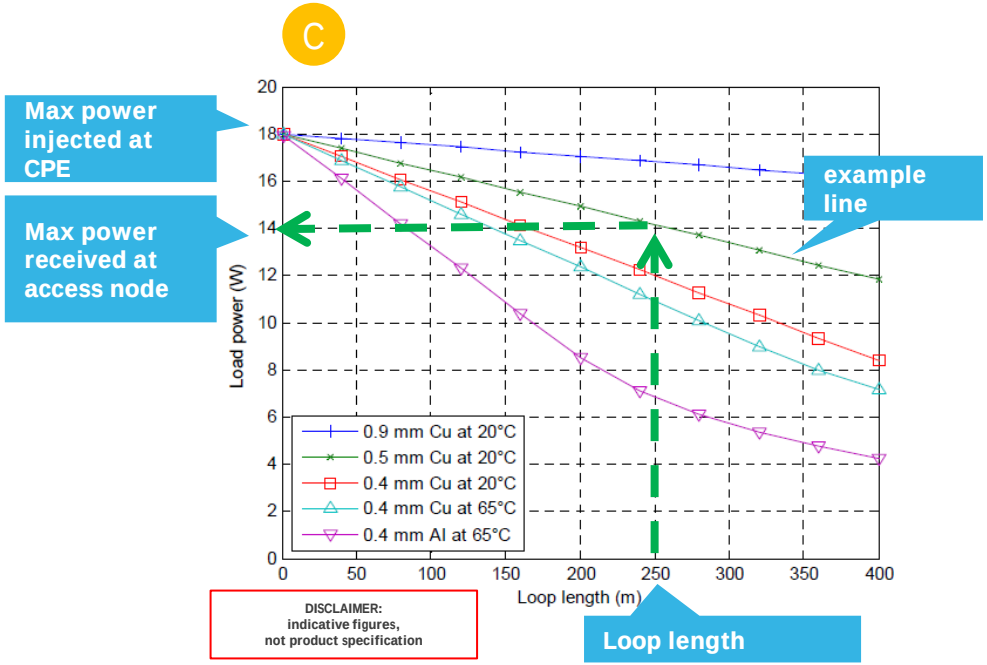
Maximum power use

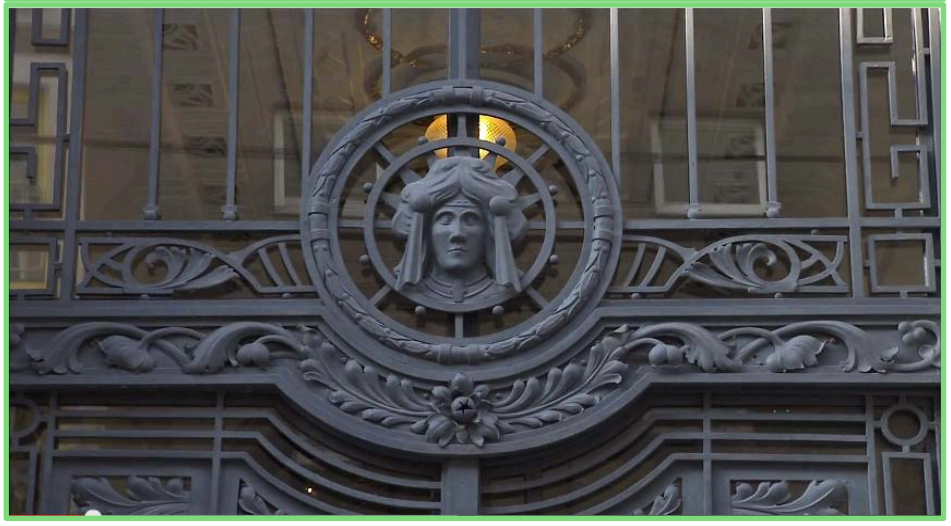
Single line power use



- Persistent Management Agent (PMA)
- DPU with dying gasp
- Distribution point managed using Yang data modeling language of the NETCONF L2 protocol



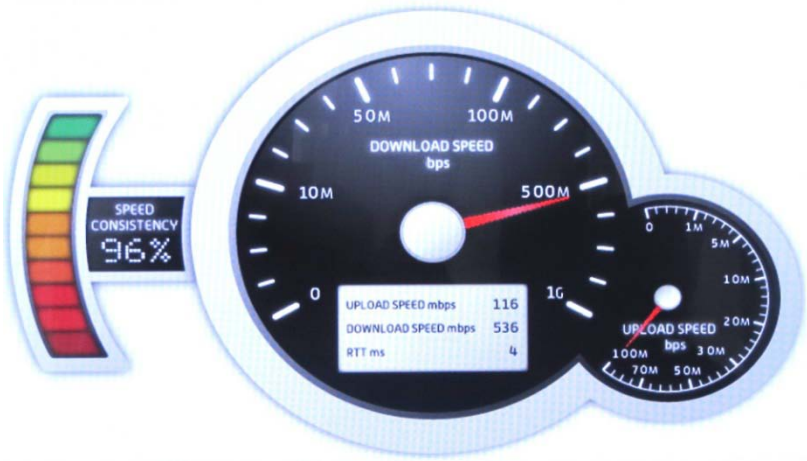




652 MBit/s US+DS TRAFFIC

(74m in-house cable)

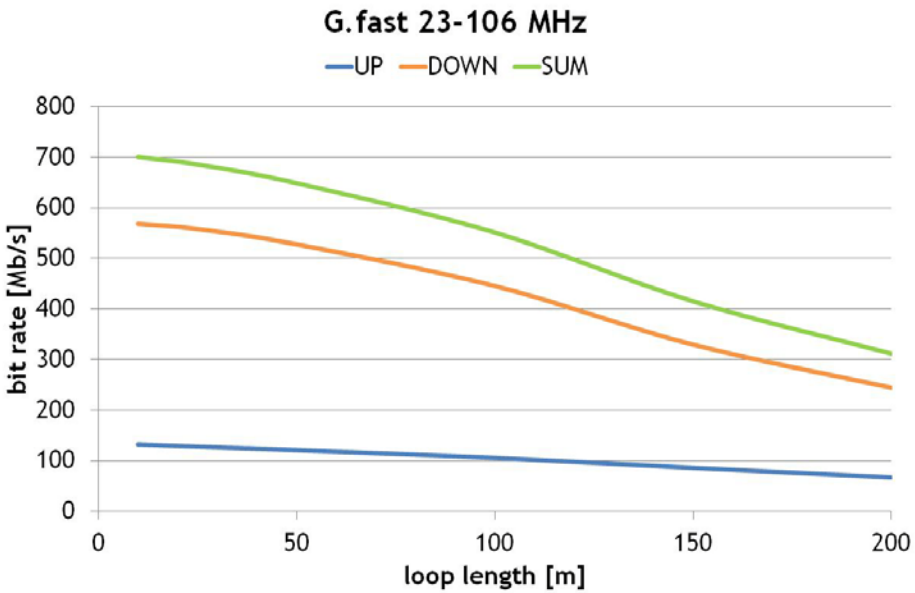
Ultrabreitband mit G.fast

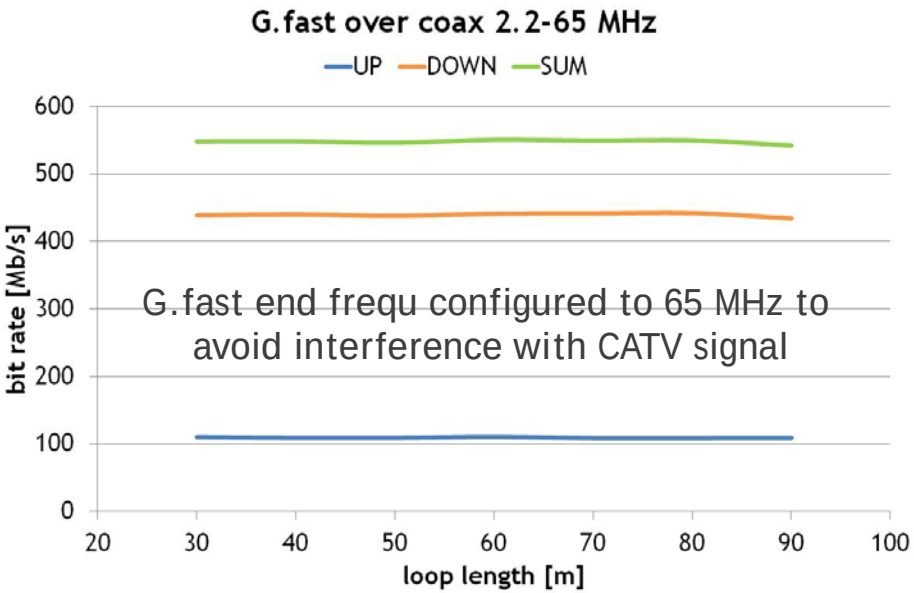


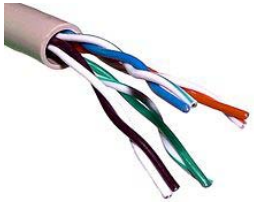
Source: A1 in cooperation with ALU

G.FAST GIVES HUNDREDS OF MBIT/S OVER LEGACY TWISTED PAIRS

ALSO WORKS ON COAX







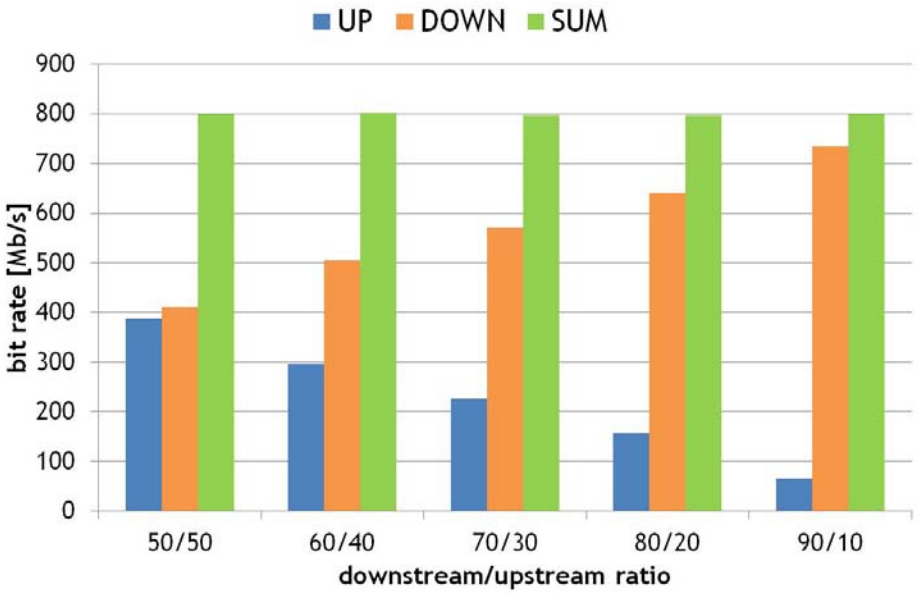
G.fast on twisted pair in overlay with VDSL2 17a

G.fast equally works on coax!

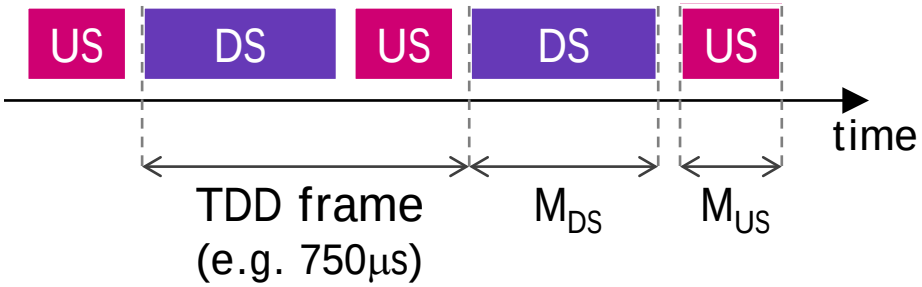
Source: BT Labs in cooperation with ALU

Source: test by ALU in operator lab

G.FAST OFFERS CONTROL OVER UP/DOWN BIT RATE RATIO



- G.fast makes use of Time Division Duplexing allowing a flexible configuration of the upstream / downstream ratio

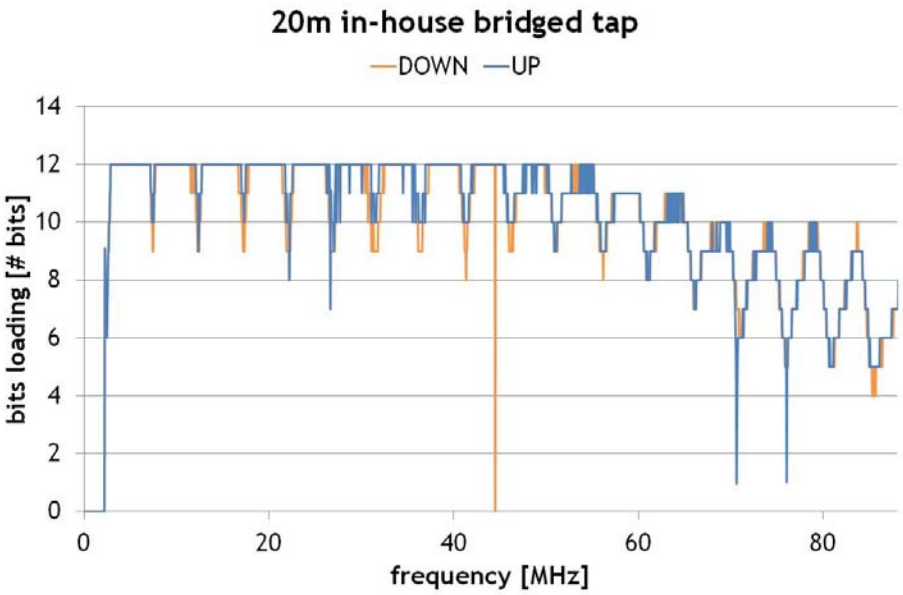


- All G.fast lines in the same cable need to be synchronized, with the same up/down split
  - In presence of crosstalk

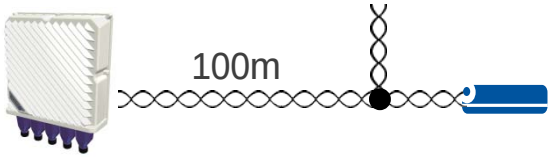
Source (bit rate figure): Orange Labs in cooperation with ALU

G.FAST ALLOWS FOR END-USER SELF-INSTALLATION

SOME (MODEST) BIT RATE LOSS IN CASE OF BRIDGED TAPS IN-HOUSE



bridged tap 2m, 10m, 20m



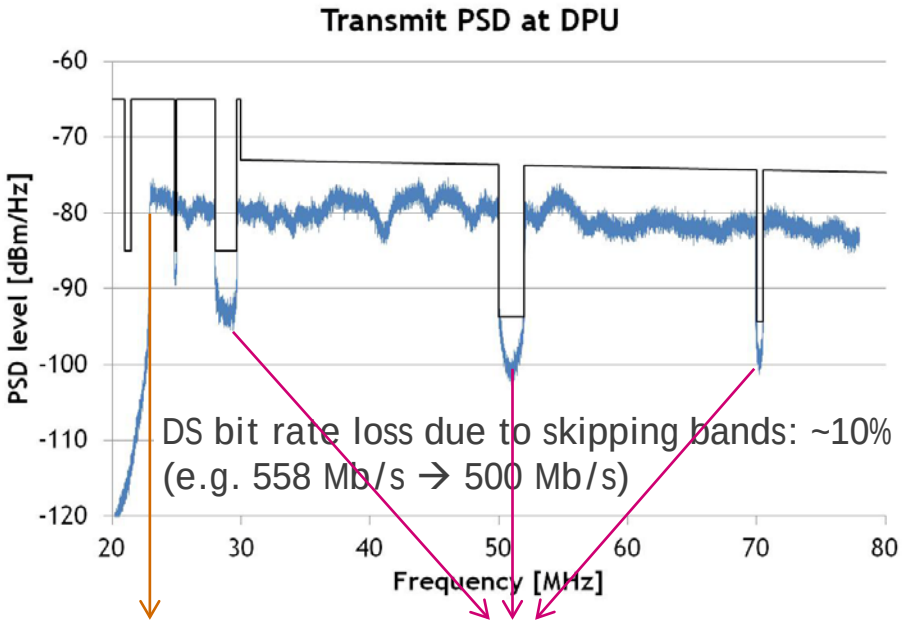
BT length	DS loss	US loss
no	0%	0%
20m	-6%	-5%
10m	-6%	-4%
2m	-13%	-8%

Bit rate loss may increase if multiple bridged taps

Source: ChuangHwa Telecom Labs (CHT-TL) in cooperation with ALU

G.FAST ALLOWS CO-EXISTENCE WITH VDSL2 AND RADIO SERVICES

- ITU-T G.9700 specifies power spectral density (PSD) mask requirements for G.fast and a set of tools to reduce the transmit PSD mask for compliance with:
  - Regional requirements
  - Operator requirements e.g. spectrum compatibility and coexistence with other xDSL access and home network technologies
  - Radio services
  - EMC requirements

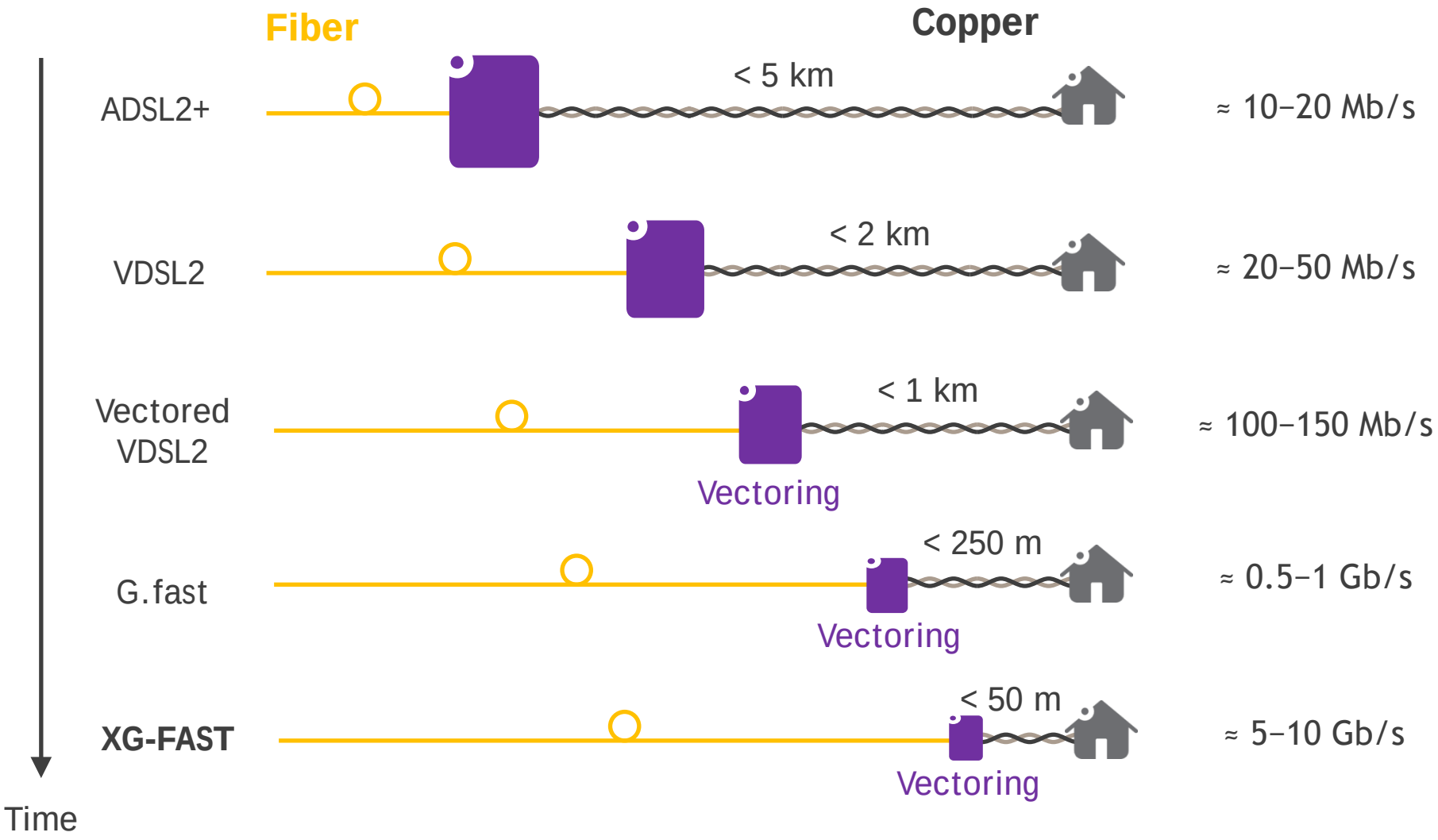


G.fast start frequency (e.g. 23 MHz) for compatibility with VDSL2 in same cable

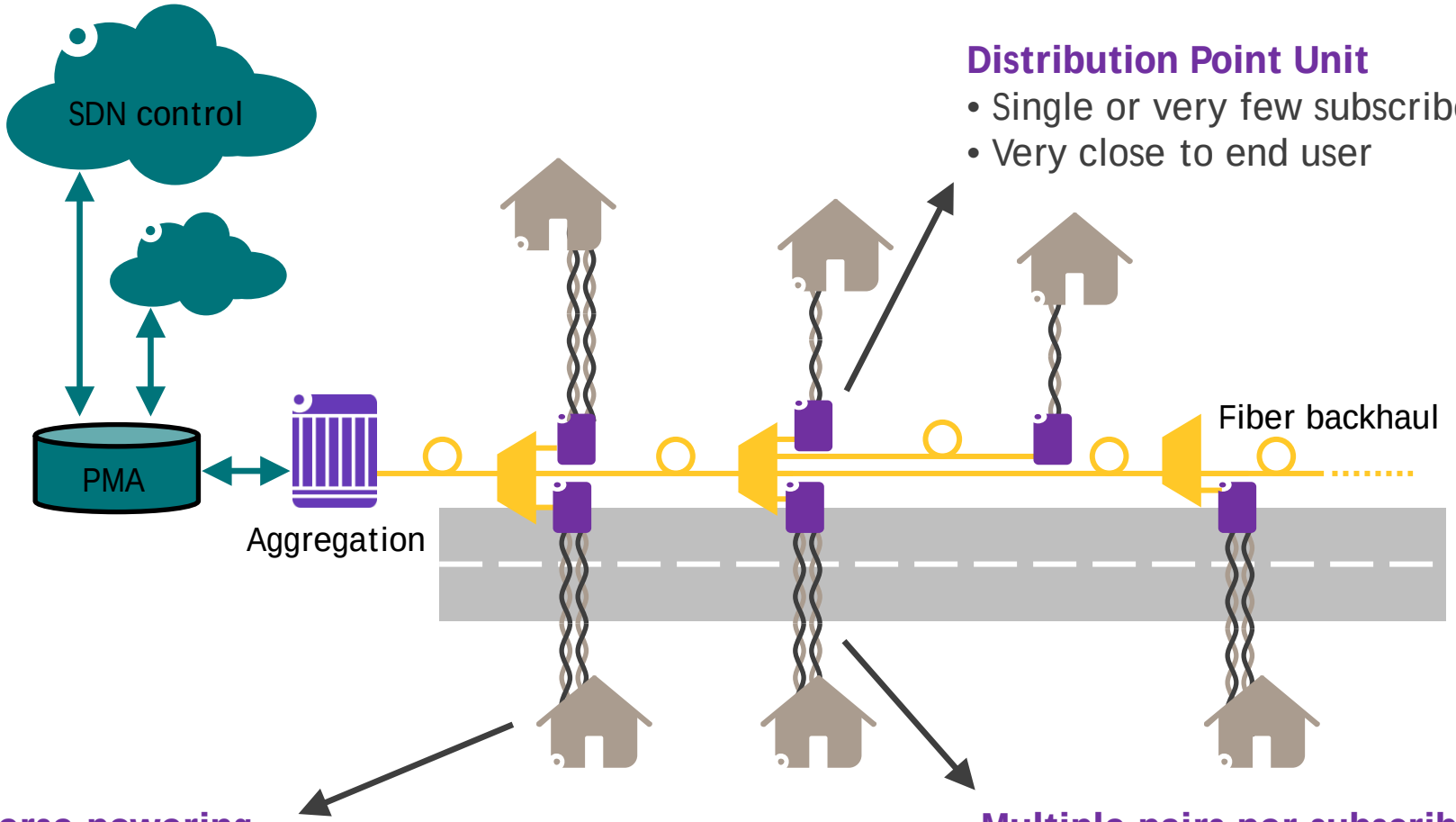
E.g. spectral notches or tone masking for protecting sensitive radio bands

Source (PSD figure): BT Labs in cooperation with ALU

GRADUAL EXPANSION OF THE FIBER NETWORK



HOMES PASSED FIBER NETWORK
HOMES CONNECTED COPPER NETWORK

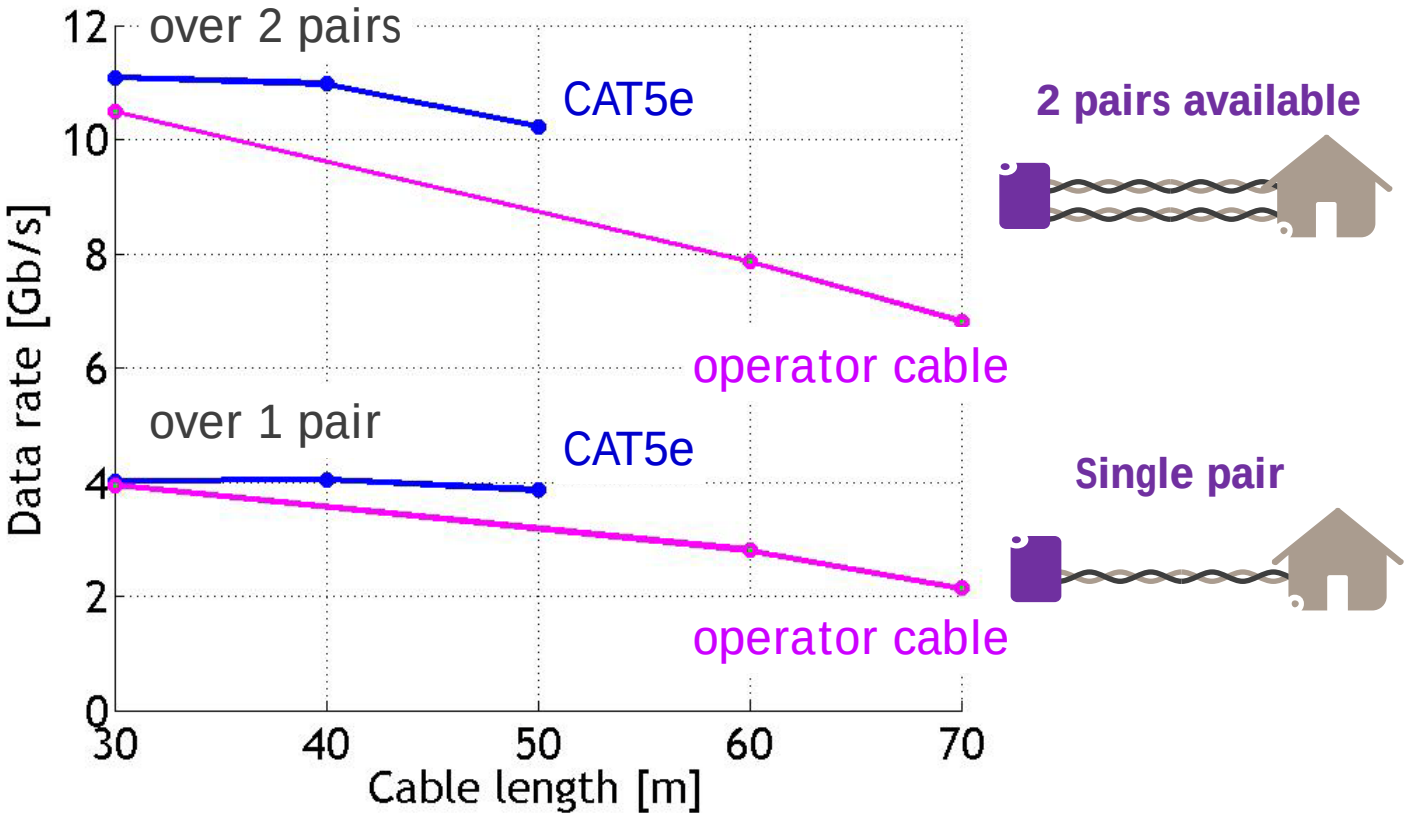


Distribution Point Unit
- Single or very few subscribers
- Very close to end user

Reverse powering
- User doesn't need to power shared hardware
- Short cables have low resistive loss

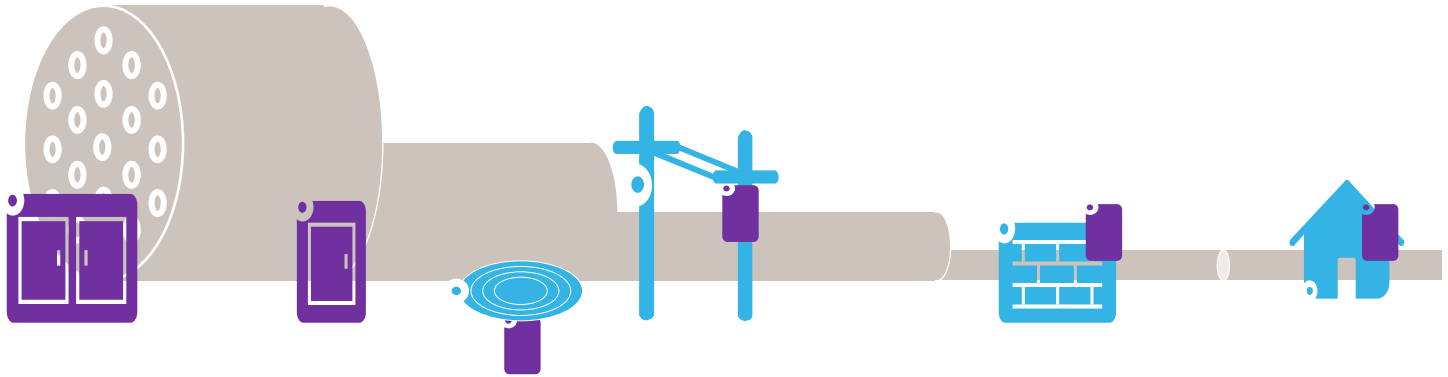
Multiple pairs per subscriber
- No/little inter-user crosstalk
- High intra-user crosstalk

LEOPARD XG-FAST PLATFORM
WORLD RECORD SPEEDS



W. Coomans et al., IEEE Globecom 2014, workshop From Research to Standards.

SPEED UP ADOPTION OF ULTRA BROADBAND SERVICES THROUGH HYBRID FIBER-COPPER NETWORKS



FTT... NODE CURB MANHOLE POLE BUILDING DRIVEWAY FRONTDOOR

VDSL2 VECT

>200 METER
>100 SUBSCRIBERS

G.fast

<200 METER
10s OF SUBCRIBERS

XG-FAST

10s OF METERS
1 SUBSCRIBER

www.alcatel-lucent.com