Enabling 4GBB via the last copper drop of a hybrid FttH deployment

White Paper on DSL – Rob F.M. van den Brink, TNO, The Netherlands, April 2011

Abstract: *Recent developments are paving the way for Telcos to offer hundreds of Mb/s to end users in a cost effective manner. These developments are to bridge the last 20-200 m of Fiber to the Home solutions via existing telephony wiring. This so called Hybrid FttH solution is considered to become an important economic enabler for 4GBB, a name referring to service packages that are so demanding in bit-rate that access rates in the range of 100 to 1000 Mb/s are required to enjoy such packages.*
Standardization has recently started for the proposed solution. This article explains the need for this new concept, its feasibility, requirements and recent developments in standardization.

1. INTRODUCTION

The quality of life and on line economy depends on the availability of ubiquitous low-cost broadband access. Demands on end-user bit-rate continue to increase as new broadband services emerge. Bit-rate demand keeps therefore growing, and each grow by a decade may demarcate a new generation of broadband services. Currently, access to second generation broadband services (2GBB, requires up to 10Mb/s, and involves fast internet and triple play) has become a commodity in many countries. The market share of access to third generation broadband services (3GBB, requires up to 100Mb/s, and involves multiple IPTV channels simultaneously and cloud computing) is currently growing. A small percentage of subscribers already has access to even higher bit-rates (>100Mb/s), but this does not necessary mean that they really use it for a 4GBB service package (up to 1Gb/s). The type of services that will be typical for a 4GBB service package is currently unknown but it will probably include more than just many HD IPTV channels simultaneously. However, for the time being, we simply assume that sooner or later there will be a massive demand for 4GBB and that access to bit-rates of up to 1Gb/s are to become a commodity.

Telcos as well as Cable Operators have their own solutions for migrating their networks to deliver broadband services (DSL via twisted pair telephony wiring and EuroDOCSIS via coax CATV wiring). Figure 1 illustrates the evolution of solutions being implemented by Telcos. The use of ADSL2 technologies over existing telephony wiring was the key enabler for a massive migration to 2GBB. Higher bit-rates are also feasible via DSL when copper loops are short. Migration to 3GBB is ongoing for Telcos via VDSL2 and when customers do not live close to the central office, fiber to street cabinets (FttCAB) is inevitable to keep/make the copper loop sufficiently short.

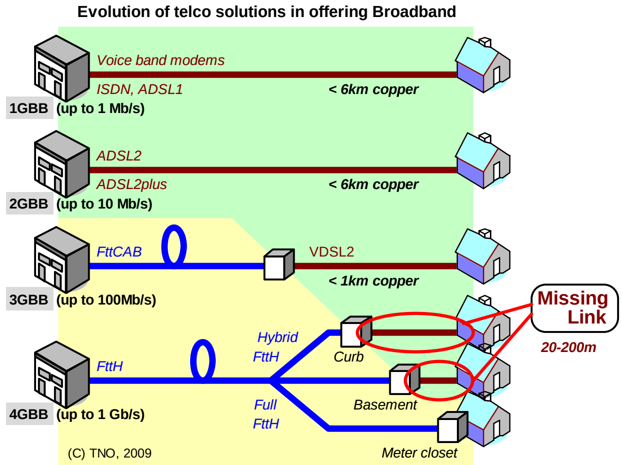

Figure 1: Evolution of Telco solutions to migrate access networks to higher bit-rates.

To deliver even 4GBB to the masses, Telcos will require another generation of access technologies to migrate their access networks. The use of FttH (Fiber to the Home) will then be inevitable for transporting hundreds of Mb/s to and from end-users. But FttH does not necessary mean that fiber is to be deployed all the way to a point ***inside*** the Home. An alternative is bringing fiber ***up to*** the Home and re-using existing telephony wiring for bridging the last 20-200m. Such an alternative may be more cost effective in several cases, since it might save installation costs and time. It enables the implementation of FttH for 4GBB in different variants, and the one that is preferred is to be selected on a case-by-case basis. *Full FttH* is selected where needed, and *Hybrid FttH* is selected when it is more attractive from a business point of view. Both solutions are fully capable of handling bit-rates of hundreds of Mb/s or more.
This approach is a new concept, and the copper technology required for such a Hybrid FttH solution is currently lacking. Nevertheless, the approach looks very promising and ITU-T-SG15 has recently started standardization of the required technology under the working name “G.fast”. This article explains the need for this new concept, its feasibility, requirements and recent developments in standardization.

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2. WHY HYBRID *AND* FULL FTTH?

Although full FttH has been available as a technology for more than 25 years, the costs for installation, digging and putting fiber into the ground are so significant that the required investment is disproportional to the actual market demand. The result is that, in many countries, the penetration of FttH is still very low compared to access solutions via twisted pair (DSL) and coax (EuroDOCSIS). It illustrates that superiority in technology alone is inadequate for what will be deployed in practice. If the required investments are disproportional with actual market demand, then such technology will hardly be deployed.

2.1 THE NEED FOR ENABLERS

Customers are continuously waiting for attractive services and subscription offers, while service providers await higher penetration of broadband access, and network providers look for an actual market demand. Therefore network providers upgrade their network capacity gradually and not disruptively because it is more cost effective. Significant steps in bit-rate were only made in the past when a cost effective enabler was available.

ADSL2 and EuroDOCSIS 2.0 were the enablers for the transition towards 2GBB. They opened a massive market for Triple Play with Fast Internet. VDSL2 and EuroDOCSIS 3.0 are the enablers for the transition towards 3GBB. They will open a massive market for IPTV. Similarly, another cost effective enabler is required for the transition towards 4GBB for the masses. Without such an enabler, the majority of subscriptions will remain at 2GBB or 3GBB rates for a long time, higher bit-rates will only be available to a small percentage of "opportunity locations", and the development of 4GBB services will be delayed significantly.

A European consortium of Telcos, industry and universities [3] believes that hybrid FttH (in addition to full FttH) will be the enabler for a *massive* transition towards 4GBB. The availability of such technology is needed [4] to reduce the high installation cost for many final fiber drops (from the street into individual homes and offices). The consortium identified that the technology for re-using the last 20-200 m of existing telephony wiring is missing. But such technology could be very suitable for delivering gigabit rates from *distribution* points like basements, poles, street corners and footway boxes to the *demarcation* points in homes.

2.2 POSSIBLE DEPLOYMENT SCENARIOS

The way FttH will be deployed via these different variants may be country/Telco specific, but a possible deployment scenario can be as follows. When a Telco prepares an area for deployment, he starts digging to put fiber into the ground. The way houses are connected at the last end will then be decided on a case-by-case basis. One group of houses in a street may be connected via fiber up to the demarcation point (e.g. in a meter closet). In other words: Full Fiber.

But in case significant installation costs and/or time can be gained for a particular group of houses, the use of a Hybrid FttH variant may be more attractive (for instance to apartment buildings, multi tenant houses or terraced houses). In such cases, fiber is brought to a node near the building (e.g. in the basement, on an outside wall, in nearby poles or in footway boxes below the street) and the existing telephony wiring is re-used for transmitting bit-rates up to 1 Gb/s via the last copper drop. If power is not available at that distribution point, the equipment can be reverse-powered [7] via existing telephony wiring from the customer premises. If a double wire pair is available, both can be used to double the bit-rate. (Double wire pairs are not uncommon; about 55% of the copper loops from street cabinets in the Netherlands are implemented as quad, and this percentage will be higher for the last copper drops). The maximum copper length of Hybrid FttH is aimed at 200m but, in practice, the majority of these copper drops may be significantly shorter.

3. IS IT TECHNICALLY FEASIBLE?

VDSL2 is aimed for 1 km or less and designed for data rates up to 200 Mbit/s via twisted wire pairs using a bandwidth up to 30 MHz [6]. The use of much higher transmit frequencies in combination with shorter loops (<200 m) enables bit-rates of hundreds Mb/s. And when a double wire pair is bonded, the bit-rate will roughly double as well.

The simple fact that wire pairs are twisted (instead of constructed in a coaxial manner) does not prevent the use of very high frequencies. Figure 2 shows measurements of differential mode transfer and crosstalk (FEXT) of a twisted pair cable up to 300MHz. This cable was shielded, had 4 wire pairs, 232 m was wound on a drum, and was of high quality (CAT5). Frequencies as high as 300MHz are still far above the crosstalk noise (FEXT) in this particular cable, and it is therefore also suitable for data transmission.

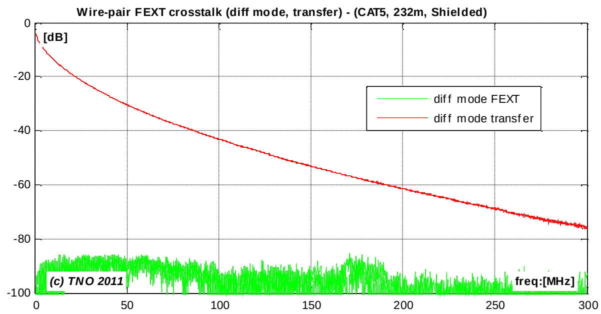

Figure 2: Measured transfer and crosstalk (FEXT) through a high quality twisted pair cable (CAT5, 232 m, shielded).

Transporting very high bit-rates via twisted pair cabling does not prevent low equipment cost either. Gigabit Ethernet is getting a commodity on consumer PC's, and is capable of transporting 1 Gb/s via 4 wire pairs over at least 100m of CAT 5 cabling. The G.HN standard is for home networking, and aimed for rates of up to 1Gb/s using a bandwidth up to 100 MHz [5].

The real challenge for transmitting via telephony cabling comes from crosstalk coupling ratios that are higher than for CAT5 cabling due to imperfections in the twist of the wires. Figure 3 shows measurements on and between various wire pairs in a typical telephony cable (378m in length), this time up to 100MHz. When the frequency is beyond 60MHz, then

the observed transmit signal becomes of the same order of magnitude as the levels for crosstalk (FEXT).
Using higher frequencies is therefore useless for transmission purposes and this puts an upper limit on the maximum bit-rate that can be transported via this cable. However the use of advanced transmission techniques like vectoring and MIMO reduces the impact of crosstalk and can increase this maximum bit-rate significantly.

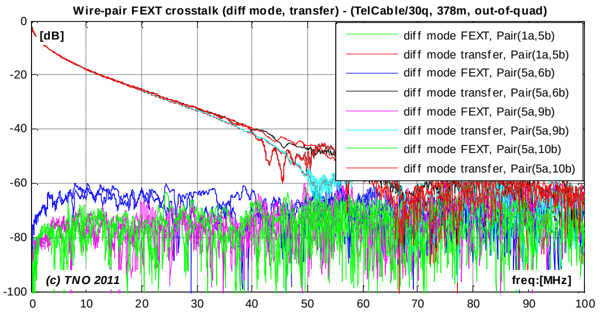

Figure 3: Measured transfer and crosstalk (FEXT) through a medium quality twisted pair cable (378 m telephony wiring, organized in 30 quads, shielded and wound on a cable drum).

Another challenge is to overcome the imperfect transmission of a cascade of different wiring segments, including cable splices and manipulation boxes (see figure 4). The same applies for egress from the cable (this might disturb broadcast radio) and ingress into the cable (impulse noise, Radio Frequency Interference / RFI). But all these challenges are not assumed to cause a fundamental problem. Since 4GBB via the last copper drop is aimed for loop lengths such as 20-200m, the curves in figure 3 will improve for these lengths. Using double wire pairs will roughly double the throughput. And the latest signal processing (error-correction, retransmission, vectoring, MIMO, etc) gives it another boost and most of it is already available for VDSL2 or under development.

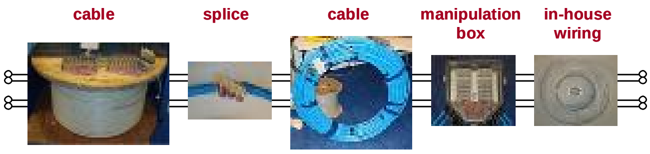

Figure 4: An arbitrary wiring topology can be modeled as a cascade of individual wiring elements to simulate the end-to-end transmission characteristics.

Although further research is required for making a more adequate prediction of potential throughput via the last copper drop, measurements of up to 500MHz have already been released [2,8]. An industrial cooperation [3] has already started to characterize all kinds of cable segments, splices and manipulation boxes, and will release this information as well. This effort includes the simulation of the cascaded behavior of an arbitrary wire topology, such as shown in figure 4. These preliminary measurements proved [2] that transmission of hundreds of Mb/s (or more) is feasible via short telephony wiring.

4. PROGRESS IN STANDARDISATION

The concept of 4GBB via the last copper drop has attracted interest from the telecommunications industry. Recent initiatives within Broadband Forum by SPAC (Service Provider Action Council, open for operators only) to develop a White Paper with potential requirements [1] and a generic presentation [2] at Broadband Forum explaining the need for this concept to a wider audience from the industry have resulted in a Broadband Forum liaison to ITU-T-SG15. In February 2011, ITU-T-SG15 started a new work item (dubbed "G.fast") as a response to that. The word "fast" stands for "Fast Access to Subscriber Terminals", and the work item concentrates on a transceiver that uses frequencies considerably above 30 MHz (probably up to a couple of hundred MHz).

4.1 FUNCTIONAL REQUIREMENTS

During the February 2011 meeting of ITU-T-SG15, several highly relevant questions were raised regarding the aimed use cases for G.fast. Functional requirements are subject for further study, but initial thoughts are in existence [1].
Topology. A typical distribution point may support about 20 customers though smaller and larger examples can be found. The typical wire length may vary significantly among different countries. The aim is up to 200 m (from distribution point up to a demarcation point with a residential gateway). Length statistics of 9 million drop-wires released [7] for the UK network indicated that a majority of these loop length is within about 70 m and are typical around 35 m, but these numbers may be different in other countries.
Transmission. The DSL signals should pass over the customer's in-premises telephony wiring exhibiting bridge taps and relatively poor balance. PSD limits of transmit signal should take into account current CISPR emission limits, although future evolution of those limits is foreseen.
Bit-rates. The aggregate bit-rate should be at least 500Mb/s (sustained US+DS aggregate) via a 30m single wire pair otherwise the Hybrid FttH concept cannot offer a service grade comparable with Full FttH. The asymmetry between up and downstream rates should be flexible. The use of bonding on two wire pairs should be considered for networks with quad cables.
Installation. This new generation of DSL should support self install for triple play services. Different backhaul technologies may be used but a key requirement is to support a mix of full and hybrid FttH scenarios, where remote equipment can be powered from the customer's premises.
Operations and maintenance. It is essential to provide performance and noise monitoring, and loop diagnostics capabilities, to enable automatic management systems to detect, diagnose and mitigate fault conditions. Zero Touch operation is the goal. In particular it should not be necessary to visit the remote in order to upgrade, downgrade or disconnect services. The remote should have self-healing capabilities to permit planned repair rather than requiring an emergency visit.
Powering. The overall power consumption must be very low because of reverse powering, and should also vary proportionally to the number of active customers. In the

extreme case where only one customer is active, the remote equipment must also be powered from that customer.

Unbundling. The requirements for support of local or sub loop unbundling is unclear at the time of writing. It may be on a physical level in one network and via higher layers (virtual unbundling, bit-stream access) in others.

Other requirements. It may be obvious that further requirements are left for further study to drive the creation of this G.fast standard. Telcos from different countries can play an important role in this by identifying their needs and use cases. The initiative has been taken within Broadband Forum / SPAC for creating a White Paper on this topic [1]. The 4GBB consortium [3] has already started to develop models for techno-economic studies and to measure and simulate the characteristics of the involved wiring.

4.2 RE-USE OF EXISTING STANDARDS

The above-mentioned functional requirements are agnostic with respect to linecode, duplexing method and other implementation aspects, but the creation of G.fast can gain from existing ITU standards related to DSL [6] and G.HN [5] for Home Networking. Both have very useful capabilities on board and both are also very different. For instance, the DSL solutions are training based, are optimized for point-point topologies and use frequency division multiplex (FDD) to separate upstream from downstream transmission. The G.HN solutions however are preamble-based, are optimized for point-to-multipoint topologies and use time division multiplex (TDD).

The current G.HN solutions support higher bit-rates than VDSL2 and use wider transmit spectra than the current DSL solutions, but the preamble solution of G.HN costs additional bandwidth (which is generally more suitable for an environment with large fluctuations in time of the channel characteristics) and G.HN does not feature vectoring (crosstalk would seriously degrade the attainable bit-rate performance). Therefore it is unlikely that G.fast becomes just a boosted variant of one (DSL) or the other (HN) but more likely a standard where the physical layer is designed by taking the best of both worlds.

The concept of reverse powering has recently resulted in an ETSI standard [7], which is directly applicable.

5. SUMMARY

4GBB is the name of a service package which is so demanding in bit-rate that access rates of up to 1 Gb/s are required to enjoy it. A Fiber to the Home solution can handle these bit-rates but the cost for bringing fiber to all houses are so significant that the required investment is disproportional to the actual market demand. Therefore an (economic) enabler is needed for a *massive* transition toward the bit-rates needed for 4GBB.

Hybrid FttH can offer this enabler by re-using existing telephony wiring in the last 20-200m. This approach can save installation costs and time in special cases, and offers an attractive addition to existing full FttH solutions. This is a new concept, for which the copper technology is currently lacking, but ITU-T-SG15 has recently started standardization of the required copper technology under the name G.fast. Since it may turn out to be the key enabler for a massive deployment of 4GBB, the interest from the industry is increasing rapidly.

6. REFERENCES

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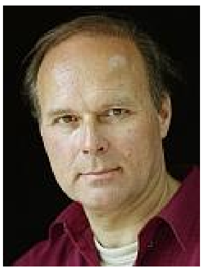
Rob F.M. van den Brink graduated in Electronics from Delft University in 1984, and received his PhD in 1994. He works as a senior scientist within TNO on broadband access networks.



Since 1996, he has played a very prominent role in DSL standardisation in Europe (ETSI, FSAN), has written more than 100 technical contributions to ETSI, and took the lead within ETSI-TM6 in identifying / defining cable models, test loops, noise models, performance tests, and spectral management. He is the editor of an ETSI-TM6 reference document on European cables, and led the creation of the MUSE Test Suite, a comprehensive document for analyzing access networks as a whole.

He also designed solutions for Spectral Management policies in the Netherlands, and created various DSL tools for performance simulation (SPOCS, www.spocs.nl/en) and testing that are currently in the market.

He has also been Rapporteur/Editor for ETSI since 1999 (on Spectral Management: TR 101 830), Board Member of the MUSE consortium (2004-2008, www.ist-muse.org) and Work Package leader within the Celtic 4GBB Consortium (2009-2011, www.4gbb.eu).