Very High Bit Rate Digital Subscriber Line (VDSL2) technology for triple play services

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Abstract—**In an Customer demand for triple-play services is on the rise, and cable operators have responded by adding services such as Internet access, VoIP, Video on Demand (VoD), and High Definition TV (HDTV) to their standard television service. Unfortunately for carriers and service providers looking to compete with cable and even satellite operators, triple-play services require a great deal more bandwidth than what is currently available over last-mile copper loops. To compete effectively for customer business and to create a future-proof network, carriers and service providers have a critical need for a fiber-fast broadband capability of 50 Mbps to 100 Mbps. While extending fiber to every home seems a logical solution, it is not feasible economically or competitively. Very-High-Bit-Rate Digital Subscriber Line 2 (VDSL2), a standard by the ITU-T. The proposed VDSL2 standard increases the spectrum allocation to 30 MHz for higher performance. VDSL2 enables fiber-fast broadband at speeds of up to 100 Mbps symmetrical—fast enough to deliver broadband applications such as the triple play of voice, data, and video.**

Keywords— **Video on Demand (VoD), High Definition TV (HDTV), Very High Bit Rate Digital Subscriber Line (VDSL)**

I. INTRODUCTION

In order to understand VDSL2's place in the industry, it is important to follow the history of the ITU standard. In June 1999, the industry cheered as ADSL was standardized by the ITU-T. According too many experts, G.992.1 (G.dmt) and G.992.2, (G.lite) were the standards the industry needed to set the stage for worldwide mass-market deployment of broadband Internet services via copper. Rollouts began, and the 2000 year, there were 5 million ADSL subscribers. Shortly after launching ADSL, the ITU-T committee realized that, while the standard was a great starting point, it needed still improvements in several areas, and they set to work on ADSL2. By 2002, the ADSL2 standard was approved and the industry hailed the extended rate and reach as the defining technologies needed to effectively compete with the cable modem market, especially in the United States. With the introduction of ADSL2+, also known as ADSL2plus, in 2003, carriers and service providers began to see the magic bandwidth numbers needed to effectively deliver video-over-DSL. The ITU standard, G.bond, also known as "BondedADSL2+," was introduced in early 2005 as a way to double the downstream data rate of copper pairs. It was most effective for customers 6 Kft or more from the central office, so it lacked the short distance and high data rates that video demands. VDSL [1] was ratified in 2003, but service providers concluded that more work was needed on the standard and the new standard, VDSL2 [2], showed the potential of much higher data rates, so the ITU-T continued to hammer out the details for the next-generation of the standard. Shortly after the world celebrated the milestone of 100 million DSL subscribers globally, VDSL2 (G.993.2) [18] was consented in May 2005. With the introduction of VDSL2, the industry will see a major transition from high-speed Internet, which is primarily a data-only service (e.g. web surfing and email), to broadband triple play: voice, video and data. Triple-play service is necessary to offer subscribers all of the essential blocks of communication and information in the same service.

The paper is organized as follows: The discrete multi-tome line coding is introduced in Section II and in Section III the frequency plans is examined. In Section IV a comparison between VDSL and VDSL2 is performed and the deployment plans are presented in Section V.

II. DISCRETE MULTI-TONE (DMT) LINE CODING

A number of factors have converged to make VDSL2 an attractive standard for carriers one of the most important being the selection of a single line-coding method, Discrete Multi-Tone (DMT) [3]. This selection eliminated the line code debate that existed in the past. VDSL2 provides ease of migration from ASDL, ADSL2+, and VDSL, since all these technologies use DMT. Discrete Multi-tone Modulation (DMT) is a multi carrier scheme that is similar to orthogonal frequency division multiplexing (OFDM) used in radio systems like the European broadcast systems for audio and video.

III. FREQUENCY PLANS

The frequency ranges available for VDSL to use are limited by the need for compatibility with other DSL technologies. In FDD [4], the NEXT crosstalk is avoided through division of the spectrum into individual frequency bands, where each band is unique for either upstream or downstream transmission. This requires that all system in the same cable use the same frequency plan.

Unlike its predecessor, which allowed choosing either DMT (Discrete Multitone) or QAM (Quadrature Amplitude Modulation) technology [5], VDSL2 only uses the DMT line-code. DMT is a method of separating a DSL signal so that the usable frequency range is separated into multiple small frequency bands, or tones. It uses up to 4096 tones which are spaced 4 kHz or 8 kHz apart. Each tone can be used for either downstream or upstream however the VDSL2 standard has defined upstream and downstream bands as well as eight different profiles for several application areas.

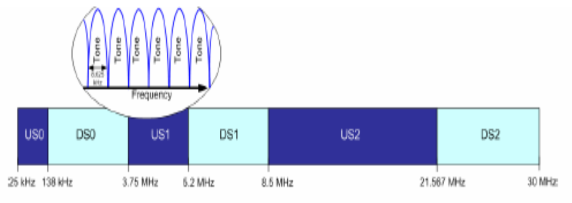

Figure 1: An exemplary VDSL2 band plan – profile 30a (30MHz bandwidth, 8.625 kHz tone-spacing)

In the following Table 1 lists all the standardized VDSL2 profiles [9] for the different regional market applications. A chip solution matching only one of these eight profiles is already allowed to claim "standard compliancy". But in order to provide a true added value for system vendors and to enable the design of a single, universal VDSL2 system that fits all deployment scenarios, the VDSL2 chip solution should support all profiles.

Profile	8a	8b	8c	8d	12a	12b	17a	30a
Bandwidth (MHz)	8.832	8.832	8.5	8.832	12.	12.	17.664	30.
Tones	2048	2048	1972	2048	2783	2783	4096	3479
Tone Spacing (kHz)	4.3125	4.3125	4.3125	4.3125	4.3125	4.3125	4.3125	8.625
Line Power (dBm)	+17.5	+ 20.5	+ 11.5	+14.5	+14.5	+14.5	+14.5	+14.5

Table 1: Profile for VDSL2

For example, European and US carriers [11] require transmit power of 20dBm or 17.5dBm (Profiles 8a and 8b). A chip solution that only features 2048 tones, 17MHz bandwidth, and 14.5dBm transmit power (Profiles 8c and 8d), like a number of pre-standard chip sets do, does not meet requirements of either of these markets. Furthermore, it's too early to determine the exact regional requirements as many carriers are still evaluating their future networks. In a nutshell: only a VDSL2 chip solution featuring up to 30MHz bandwidth capability, up to 20dBm transmit power, and up to 4095 tones can provide the required flexibility and enable system manufacturers and service providers to address all regional market applications with a single hardware platform.

From ANSI, ETSI, and ITU-T [13] three different frequency plans have been proposed as shows in the following figure.

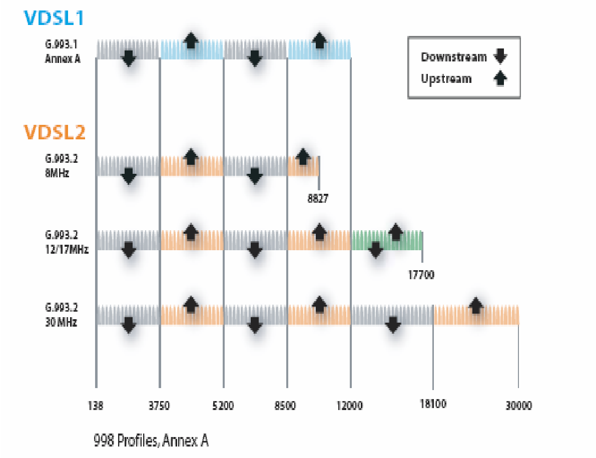

Figure 2: VDSL2 frequency plans

Each plan has four bands, two for the downstream transmission, and two for the upstream transmission. For plans 997 and 998, the four bands are fixed while for the Fx plan, the first two bands are fixed but the last two can be adjusted depending on the value of the frequency Fx. Moreover the plan 998 is more suitable for asymmetric services in constrict the plan 997 is much more suitable for symmetrical services.

The Fx plan was proposed to provide a flexible solution allowing deployment of either asymmetrical or symmetrical services by simply moving the Fx frequency delimiter. Form the above plan the 998 plans have been selected by ANSI for USA and Japan market. In Europe ETSI has selected the plan 998 and 997 for asymmetric and symmetric services respectively. ITU-T has specified all three frequency plans with the recommendation G.993.2.

IV. COMPARISON VDSL –VDSL2 STANDARDS

The new VDSL2 standard offers, compared to VDSL, several new features. These added functionalities explained below enhance bit-rate and service coverage while ensuring high levels of QoS for voice and video transmission - hence facilitating the convergence of all broadband services onto a single network. The features are the following:

Higher Bit Rates: A frequency spectrum of up to 30 MHz as opposed to 12MHz with VDSL1 and 17MHz in pre-standard solutions results in 100 Mbit/s symmetrical data rates - much higher than the maximum of 70/30 Mbit/s in early VDSL1 solutions.

ADSL Long Reach (LR) Performance: ADSL-like long reach performance is one of the key advantages of VDSL2. LR-VDSL2 [6-7] enabled systems are capable of supporting speeds of around 1-4 Mbit/s (downstream) over distances of 4 to 5 km, gradually increasing the bit rate up to symmetric 100Mbit/s as loop-length shortens. LR-VDSL2 is implemented by using frequencies down to 25kHz in combination with the ADSL PSD mask supporting 20dBm transmit power. The upstream band in this case is allocated up to 138kHz / 276kHz, also referred to as "Upstream Band-0" or "Extended Upstream Band-0". The VDSL2 downstream band DS0 operates as an extended ADSL band, reaching as high as 3.75MHz as opposed to 1.1MHz and 2.2MHz used in ADSL and ADSL2+ respectively.

Advanced QoS functionality: Quality of Service (QoS) [10] is of particular concern for the continuous transmission of video and voice. Therefore the VDSL2 standard defines an inherent pre-emption mechanism giving higher priority to the delay-critical voice and video packets over other data packets such as email messages, web pages etc. Pre-emption essentially means that a high priority packet (such as voice) will always have a "right of way" over lower priority packets. Pre-emption can be explained using the example in figure 3. Data packets with different priority (voice, data, video-gaming) have to be transmitted through the VDSL2 chip. In order to provide the desired quality (no echo, no delay for on-line gaming) certain delay requirements have to be met. In example A, where a 100Mbit/s connection is assumed, there is no delay interference between the red high priority voice packets and the yellow low priority data packets. In example B however, where a lower speed 1Mbit/s link is assumed, delay becomes an issue as the packet transmit time increases due to the lower speed. The transmit time of packet #2 violates the timing requirements of the voice packet and would therefore cause jitter in the voice packet transmission which means echo in a voice link. This will be the case with any regular system using first-in-first-out (FIFO) technique. A Pre-Emption enabled system however will stop the transmission of the low priority data packet until the transmission of the high priority voice packet is completed.

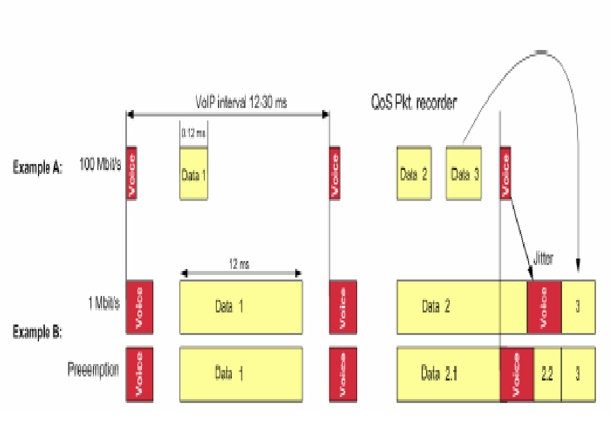

Figure 3: Motivation for packet pre-emption

Through this feature disturbing echo in a voice call can be avoided.

Dual Latency: Two independent latency paths and dual interleaving (better noise protection and higher security) and two bearer channels using for transport of user information improve the efficient and reliable handling of different data rates which is a key for high quality Triple Play applications.

Data interleaving and Reed-Solomon coding [17] protect the signal against burst noise, i.e. noise with the length of approx. 500µs which is often caused by power line interference. This burst noise protection however comes with the penalty of a higher latency, or delay. While video traffic is not affected by high latency, this is not true for voice. Therefore by implementing two independent latency paths the interleaving and Reed-Solomon coding can be independently selected to provide the optimum of burst noise protection as well as latency for each traffic class.

ADSL Compatibility and Interoperability: Due to its DMT nature and ADSL-like functionalities mentioned above, including Framing, Interleaving, and Trellis/Viterbi coding, VDSL2 [8] includes all technical prerequisites to address the ADSL backwards compatibility issues ideally. A fully VDSL2 standard compatible chip solution would be able to perform as a VDSL2 as well as an ADSL2/2+ device. This enables operators a smooth, gradual and efficient network transition towards VDSL2 with only a single technology and allows them to cover all xDSL service applications with a single network.

V. DEPLOYMENT ANALYSIS

VDSL system deployment [19] is based on fiber optics links as shown in figure 4. The deployment of optical fiber from the central exchange deep into the distribution network enables the implementation of xDSL innovations. In this general scheme the transport network uses various networks such as ATM, IP, or SDH and it is connected with the Central Exchange. Local exchanges and Street Cabinets are connected with the Central Exchange through fiber optical links. The network termination units such as VTU-R, which provide various interfaces, are located at the customer premises.

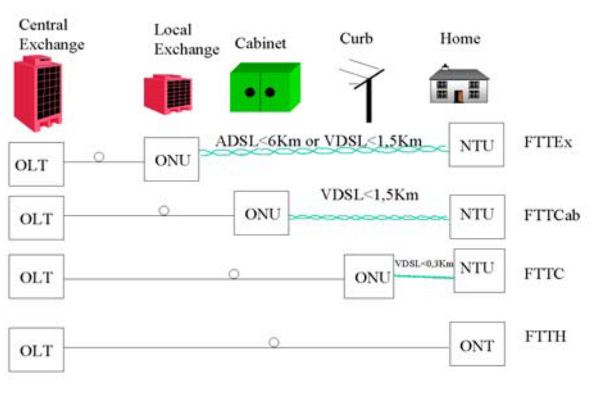

Figure 4: Deployment Scenarios

In the Central Exchange, there is an Optical Line Termination (OLT) unit and the optical network unit (ONU) is located at the Local Exchange and at the Street Cabinets respectively. Because xDSL technologies bring the fiber to the home, we have various configurations how to connect the ONU with the end customer. Fiber access networks namely Fiber to the Exchange (FTTEx), Fiber to the Curb (FTTC), Fiber to the Building (FTTB), and Fiber to the home (FTTH) [14-15-16], are technologies to move fiber to the home and in the case FTTH into the home.

For carrier's operators fiber extension is fast becoming a hot issue. With VDSL, carrier's operators are already taking advantage of the last mile copper loop to deliver fiber-fast broadband. VDSL2 will enable carriers to deliver even higher-bandwidth. in Multi-Tenant/Multi-Building Unit (MxU), Fiber to the Basement (FTTB), Fiber to the Node (FTTN), and Fiber to the customer (FTTC) [12]. With VDSL2-based services, carriers can reach the largest possible number of subscribers with fiber-fast broadband services. With a copper loop length of 5,000 feet from an RT, a curb, or a building, carriers can reach over 90 percent of their customers, while a service radius of 6,000 feet allows them to reach more than 99 percent of customers.

VI. CONCLUSION

In this paper, we have presented a new technology VDSL2 for provisioning triple play services. We discussed the proposed type of modulation and the frequency plans. The comparison between VDSL and VDSL2 are examined and a deployment analysis is presented.

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