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ESTIMATION OF BANDWIDTH UTILIZATION FOR SHDSL LINK WITH EFM TECHNOLOGY

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Background. The EFM technology is widely used in access network and assumes transformations chain of the Ethernet-signal for its distribution and further transmission through multiple copper lines named pairs. Multipairs mode is used in order to increase the capacity of the link. But copper pairs may have a different parameters and therefore different throughput. In this case non-equal distribution of the Ethernet traffic is used between pairs. But this approach requires transmitting some identificators in order to create original Ethernet frames at the receiving side. These identificators will impact on bandwidth utilization for multipairs connection.

Objective. The aim of the paper is theoretical and practical researches of bandwidth utilization for multipairs SHDSL/EFM connection in depending on traffic type.

Methods. Study all known publications and standards concerning EFM technology. Analyzing frames format for protocols which are used for SHDSL systems with EFM in order to calculate relation between payload and special data. Installation of the SHDSL link with EFM for practical researches.

Results. The theoretical and practical results concerning the bandwidth utilization for multipairs mode are achieved.

Conclusions. Methods of researches and their results may be used for estimation of the real throughput of SHDSL/EFM links during service level agreement (SLA) conclusion with customers.

Keywords: SHDSL; EFM; bandwidth; throughput.

Modern telecommunication systems are built in accordance with conception of NGN (Next Generation Network), where Ethernet is used as a unified transport technology. It corresponds also to such important area of general network infrastructure as a multiservice access network. According to NGN conception subscribers should have the opportunity to manage the services they used. Thus subscribers are occupying key position in a telecommunications process. Therefore complex of equipment and environment between subscriber and network access node now have the name "The first mile" and not the "last mile" as was before. Originally Ethernet technology was designed for using in local computer networks. However this technology is not fitted for traffic transportation through different transmission system. This defect can be explained by initially absence of monitoring, control and diagnostic features to support the necessary level of QoS (Quality of Service). The second problem connected with Ethernet stream distribution between copper pairs in SHDSL link and assembling these fragments in holistic stream at opposite side of the link. There are two approaches to resolve this problem. First of them is “byte-to-byte” equal distribution of the Ethernet fames between pairs transmitters. This method is widely used in “traditional” SHDSL systems and sufficiently simple to realize. But practically parameters of pairs may have the differences. In this case common bandwidth of the SHDSL link will be defined by pair with worst parameters, although rest of pairs can transmit a data with more rates. Therefore it is needed to have such method which will allow distribute the Ethernet traffic between pairs in depending on their rates capability. Thus second method is non-equal distribution Ethernet stream between pairs. Despite on expected efficiency concerning capacity of the M-pairs SHDSL link this method is more complex and needs to use a segmentation procedure with fragments numbering. This circumstance will impact on bandwidth utilization of M-pairs link. But due to common efficiency of M-pairs capacity utilization this method is used in modern SHDSL equipment for establishing a first mile from customer to provider’s access node. This method is named PAF (PME Aggregation Function) and described in EFM (Ethernet in First Mile) standard, which now included in IEEE 802.3 standard and represented there as section 5. EFM commonly provides practically transparent transmission of Ethernet frames with adding the functions of monitoring, diagnostics and quality parameters control of the transmission. All these possibilities united in general term named OAM (Operation, Administration and Maintenance). There are two EFM standards for copper lines – 2Base-TL (2.7 km with 2.3 Mbit/s rate through the copper line with 0.4 mm diameter) and 10PASS-TS (0.75 km with 10 Mbit/s rate through the copper line with 0.4 mm diameter). The structure of SHDSL transmission pass with elements of EFM technology is shown on Fig.1.

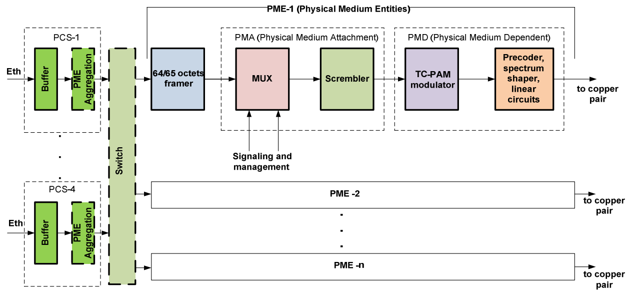


Fig. 1. SHDSL EFM transmission passes structure

On this figure we can see n independent passes, which named PME (Physical Medium Entities). Each PME consist of the following elements: 64/65 octets framer; MUX for multiplexing the payload and services data; scrambler to create a sufficient number of transitions; TC-PAM modulator based on Ungerboeck principals; precoder, spectrum shaper and linear circuits. The differences relatively to SHDSL standard G.991.2 are only in encapsulation method. SHDSL uses HDLC frame and SHDSL with EFM uses 64/65 byte framing. But the main difference EFM is the distribution method of Ethernet traffic between pairs. For SHDSL systems which are designed in accordance with EFM principals method PAF is used.

Principle of PAF is shown on Fig.2.

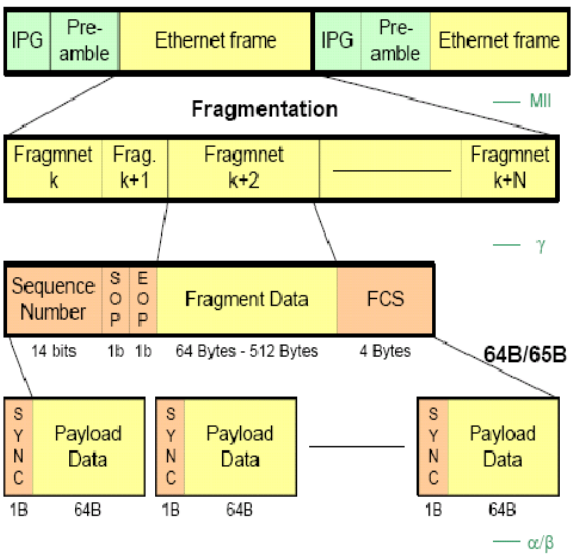


Fig. 2. PAF principle

During the PAF procedure all Ethernet frames are being segmented into fragments 64… 512 bytes long depending on initial Ethernet frame size. Exceptions are Preamble and IPG (Inter Packet Gap). In order to reconstruct initial Ethernet frame at receiving point fragments numbers are added. Fragments number consists of 14 bits. Also SOP (Start Of Packet) and EOP (End Of Packet) one bit each are present. Combination of these bits shows to which part of initial Ethernet frame fragment belongs to (beginning, middle or end). Check sum named FCS (Fragment Control Sequence) completes the fragment and has 4 bytes length. All fragments are being distributed between PMEs depending on transmissions speed which is set in them. Numbers of fragments are assembling in integral Ethernet frame at the opposite side of line. Due to adding the special fields (6 byte length) during the PAF procedure should expect the decreasing of the bandwidth coefficient usage in comparison with one pair mode. For example shortest fragment includes 70 bytes were 64 bytes is payload and longest fragment has 518 bytes (512 bytes are payload). Therefore PAF procedure decreases the bandwidth utilization for 1.16…8.5%.

The goal of present researches is theoretical and practicak estimation of bandwidth utilization for SHDSL link which is built in accordance with the standard 2Base-TL of EFM.

An estimation was performed both for the one pair mode, where standard 2base - TL differs from SHDSL only by the Ethernet encapsulation method, and for the M-pairs mode, where principle PAF is used.

The estimation of bandwidth utilization coefficient was performed both theoretically and practically. Researches were performed for different traffic type and number of copper pairs.

Theoretical calculations are based on the analysis of the ratio between payload fields and other special fields (headers, checksum, etc) which take a place in stack of protocols and technics used for transmission: from subscribers application to directly TC - PAM linear signal. As widely known from OSI model, TCP/IP protocols stack looks like is shown on fig. 3.

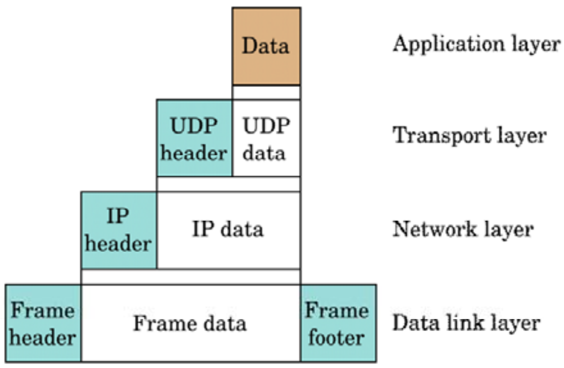


Fig. 3. TCP/IP protocols stack

As shown on Fig.3 encapsulation method is used for transmission the data from upper layer (applications) to Data link Layer (Ethernet). Packets for all layers have the headers which are being used for addressing, identification and others purposes. All of these headers decrease the bandwidth utilization. Common coefficient of bandwidth utilization may be defined from following formula:

$C_{BU} = C_T * C_N * C_D * C_F * C_{PAF}$, where:

C_T – coefficient for transport layer (UDP/TCP;

C_N – coefficient for network layer (IP);
C_D – coefficient for data link layer (Ethernet)
C_F – coefficient for framing (SHDSL and 64/65 byte);
C_{PAF} – coefficient for PAF.

All these coefficients can be defined as ratio between payload part of corresponding packet and full its size. Packet size depends on the application. The structure of packets for all layers can be find in the relative RFC documents and other sources. Structure of PME's frame is described ITU-T G.991.2 recommendation and IEEE 802.3 standard.

The results of calculations for different type of traffic (applications) are presented in Table.1.

Table 1. ***Theoretical calculation results***

Traffic type	Ethernet frame size	Coefficient of bandwidth utilization		
		1 pare	2 pares	4 pares
VoIP	76	0.48	0.39	0.38
Web(HTTP)	1518	0.91	0.89	0.88
FTP	1518	0.91	0.89	0.88

For practical researches the natural model of SHDSL line was built based on Watson EFM (SZ.868.V654) modems. The scheme of line is presented on Fig.4.

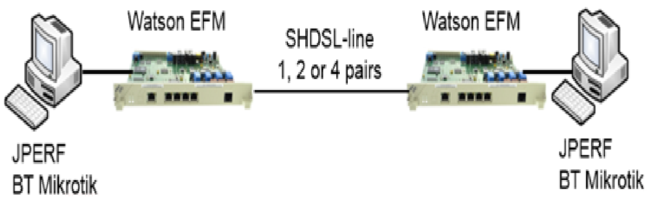
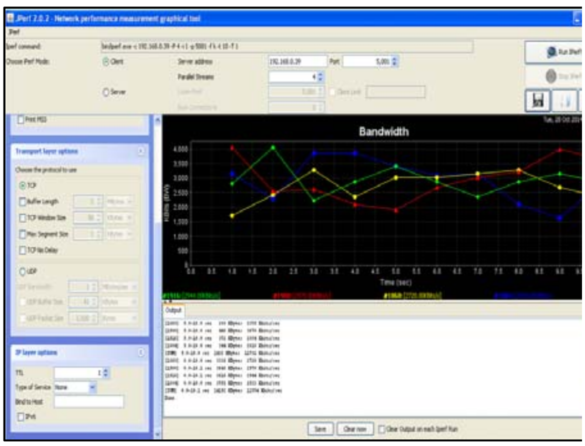


Fig. 4. The scheme of SHDSL line with EFM

The programs JPERF 2.0.2 and Bandwidth Tester (BT) from Mikrotik company were used for traffic generation and bandwidth utilization analysis:



The results of practical researches are shown in Table.2.

Table 2. ***Practical results of researches***

Traffic type	Ethernet frame size	Coefficient of bandwidth utilization		
		1 pare	2 pares	4 pares
VoIP	~76	0,51	0,46	0,41
Web(HTTP)	1518	0,95	0,94	0,93
FTP	1518	0,95	0,94	0,93

Conclusion

The technique of PAF that is used in 2Base-TL standard is effective in order to increase common bandwidth in M-pairs mode but some losses of bandwidth utilization take a place due to necessary to have additional fields for aggregation process control. Losses of bandwidth utilization are in limits of 1.16…8.5% for PAF only and depend on the quantity of pairs and traffic type. Common coefficient of bandwidth utilization varies from 48 to 91 percent.

The minimum coefficient of bandwidth utilization corresponds to shortest Ethernet frame which is specific for VoIP packets.

Differences between theoretical estimation and data of practical researches are within the limits of 3.6%.

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Оцінка коефіцієнту використання перепускної спроможності SHDSL-лінії з технологією EFM

Проблематика. Технологія EFM, яка поширена на мережах доступу по мідним кабельним лініям, передбачає низку перетворень Ethernet-сигналу для його розподілення та передачі по багатьом парам кабелю з метою підвищення перепускної спроможності з'єднання. Так як пари кабелю можуть мати різні передаточні характеристики, то застосовуються методи нерівномірного розподілу Ethernet-потоку між парами. Це призводить до потреби передавати певні ідентифікатори параметрів передачі, що викликає зниження перепускної спроможності багатопарного з'єднання.

Мета досліджень. Аналітичне та практичне дослідження коефіцієнту використання перепускної спроможності багатопарного з'єднання SHDSL з EFM у залежності від виду трафіку, що передається.

Методика реалізації. Аналіз всіх відомих публікацій та стандартів, присвячених технології EFM. Аналіз форматів фреймів протоколів, що використовуються в SHDSL системах з EFM, з метою вирахування співвідношення між корисними та службовими даними. Побудова натуральної моделі лінії з SHDSL EFM та практичні дослідження її перепускної спроможності.

Результати досліджень. Одержані теоретичні та практичні результати щодо коефіцієнту використання перепускної спроможності у багатопарному з'єднані SHDSL з EFM.

Висновки. Методика досліджень та одержані результати можуть бути використані для оцінки реальної перепускної здатності ліній SHDSL з EFM у процесі укладання угод про якість надання послуг користувачу.

Ключові слова: SHDSL; EFM; перепускна здатність

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Оценка коэффициента использования пропускной способности SHDSL-линии с технологией EFM

Проблематика. Технология EFM, широко используемая в сетях доступа по медным кабельным линиям, предполагает цепочку преобразований Ethernet-сигнала для его распределения и передачи по многим парам кабеля с целью увеличения пропускной способности соединения. Так как пары кабеля могут иметь разные передаточные характеристики, то используются методы неравномерного распределения Ethernet-потока между парами. Это приводит к потребности передавать определенные идентификаторы параметров передачи, что вызывает снижение пропускной способности многопарного соединения.

Цель исследований. Аналитические и практические исследования коэффициента использования пропускной способности многопарного соединения SHDSL с EFM в зависимости от вида передаваемого трафика.

Методика реализации. Анализ всех известных публикаций и стандартов, посвященных технологии EFM. Анализ форматов фреймов протоколов, которые используются в SHDSL-системах с EFM, с целью вычисления соотношений между полезными и служебными данными. Построение натуральной модели линии с SHDSL EFM и практические исследования ее пропускной способности.

Результаты исследований. Получены теоретические и практические результаты относительно коэффициента использования пропускной способности многопарного соединения SHDSL с EFM.

Выводы. Методика исследований и полученные результаты могут быть использованы для оценки реальной пропускной способности линий SHDSL с EFM в процессе заключения договоров о качестве предоставления услуг пользователю.

Ключевые слова: SHDSL; EFM; пропускная способность