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A Survey on Energy Efficient Transmission in Digital Subscriber Line

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ABSTRACT: As communication is widely through internet data efficient transmission is an important concern. Digital Subscriber Line (DSL) is a modem technology that uses existing telephone lines to transport high-bandwidth data, such as multimedia and video, to service subscribers. It brings high- bandwidth information to homes and small businesses over ordinary copper telephone lines. Although DSL and cable both provide high speed broadband Internet, fastest connection is possible with DSL since this type of connection is not shared with other users. Cable tends to be a public service, ie more users will be connecting to the Internet which reduces the speed of transmission. The main problem faced during the transmission in DSL is signal attenuation and crosstalk. Different techniques are proposed for improving the energy efficiency in DSL. In this paper we made a comparative study of parameters such as crosstalk, computational complexity and efficiency of Discontinuous Operation, Stable Sleep Mode Optimization and Dynamic Resource Allocation. The review shows Dynamic Resource Allocation is well suited for the energy efficient transmission through DSL.

KEYWORDS: DSL, G.fast, TDD, DOI, Dynamic Resource allocation

I. INTRODUCTION

Due to the wide use of internet the communication is mainly through internet. Digital subscriber line or Digital Subscriber Loop (DSL) is a type of Internet technology that have high speed transmission of digital data via the wires of a telephone network. DSL does not interfere with the telephone line, thus the same line can be used for both Internet services as well as regular telephone services. One thing to note is that the distance in which the data has to travel does somewhat reduce the upload and download speed. DSL splits the frequencies used in a solitary phone-line into two main bands. The high frequency band is used to send ISP data, and the low-frequency band is used to send voice data. Because of this technology, we are able to enjoy Internet access while using the telephone at the same time. DSL can be installed easily and work alongside any existing equipment for your standard phone line. When high frequency bands are used for data transmission there exists crosstalk due to the limited spectrum. Signal attenuation is the loss of transmission signal strength. As attenuation increases, the more distorted and unintelligible the transmission. Thus in order to avoid these problems and to make energy efficient transmission in DSL, here deals with different techniques to enhance overall efficiency in transmission. The techniques are Discontinuous Operation, Stable Sleep Mode Optimization and Dynamic Resource Allocation. G.fast is a DSL protocol standard for local loops shorter than 500 m, with performance targets between 150 Mbit/s and 1 Gbit/s, depending on loop length. Energy Efficiency was a serious issue faced by them, and thus introduces Discontinuous Operation.

Vectoring is the process of crosstalk cancellation on active lines during the discontinuous operation. In combination with vectoring process discontinuous operation becomes more efficient. In Stable Sleep Mode Optimization, the use of sleeping states was optimally chosen under certain conditions in order to increase efficiency in the data transmission. In order to facilitate energy efficient transmission in Dynamic Resource Allocation data frame is divided into Normal Operating Interval (NOI) and Discontinuous Operating Interval (DOI). NOI needs large precoder matrix because all lines are involved in common vectoring group. As in the case of DOI lines are subdivided into smaller

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groups thus require small precoder matrix, and transmitted as Time Division Multiple Access (TDMA) manner. The paper studied these three technologies in detailed based on the simulation results and mathematical analysis. Chapter II discusses the concepts of discontinuous operation, stable sleep mode optimization and Dynamic Resource Allocation. In Chapter III, a comparative study on various parameters such as cross talk, computational Complexity and Efficiency is performed for the idle technique and Chapter IV concluded the survey.

II LITERATURE SURVEY

DISCONTINUOUS OPERATION IN VECTORED G.FAST

A G.fast uses Time Division Duplexing method consists of discrete multitone modulation scheme allocated to symbols on Down Stream (DS) and Up Stream (US). [1] This allocation to each transmission direction is controlled by DS/US demarcation point. The Transmit Opportunity (TXOP) is bounded time interval in which stations are permitted to transmit a series of frame. In the normal operation mode L0 the TXOP comprises of all symbol (Line 1 in Figure 1) in the low power L2.0 mode transmission is restricted to first few symbol positions in any transmission direction (Line 2 and 3 in Figure 1). Within TXOP, until the transmit buffer is empty transceiver remains active. The transceiver is said to be in discontinuous operation, from that point onwards to the end of TXOP and G.fast may move into low power state.

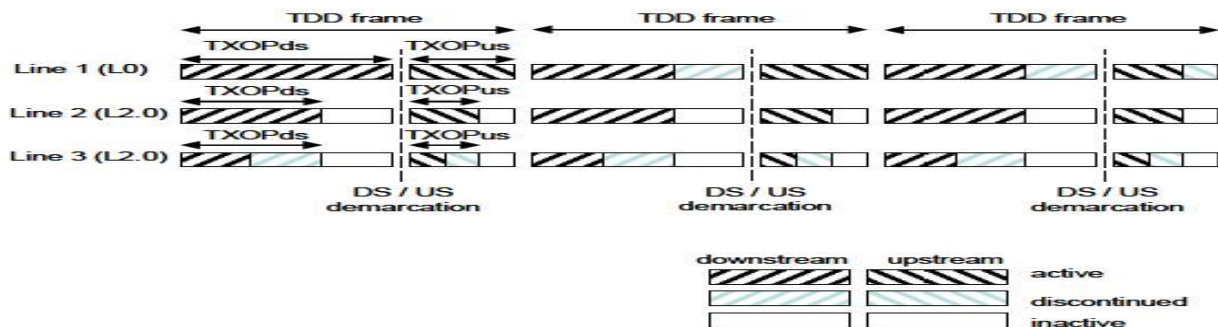


Fig 1: A TDD frame

Vectoring is the process of increasing bandwidth by the process of noise cancellation. The term vectoring refers to the digital signal processing (DSP) computations involved to cancel the crosstalk. The computation involves multiplying precoder matrices with $N \times 1$ data sets or vectors representing the transmit signals. Vectoring phenomenon is accompanied with the discontinuous operation in order to increase the efficiency. Additive noise as well as the crosstalk interference which means interference caused due to the leakage of signals which were transmitted on the same bundle of fibres are the noises effected in the receiver part. This crosstalk interference is mainly from active users. Consider when all lines are active simultaneously, and vectored the noise in receiver will comprise additive noise only. The set of active lines are represented by A and the discontinued lines by D respectively. In discontinuous operation the user signals denoted as UD contain no information, while the signal on the discontinued line XD Contains precompensation information and will typically be non zero.

So when any one of the lines are active they needs precompensation signal in order to cancel residual crosstalk exist on the line, even if the precompensation information signals are small there exist little energy saving. Vectoring in discontinuous operation consists of muted vectoring and discontinuous vectoring. The first method is to mute the output of precoder, thus power consumed by the analog components can be reduced. But the characteristics of vectoring are lost. so muting the precoder output introduces residual noise into the active lines. Thus the benefits of vectoring are lost. In discontinuous vectoring, the output of the precoder is forced to zero by controlling the input data. Since the

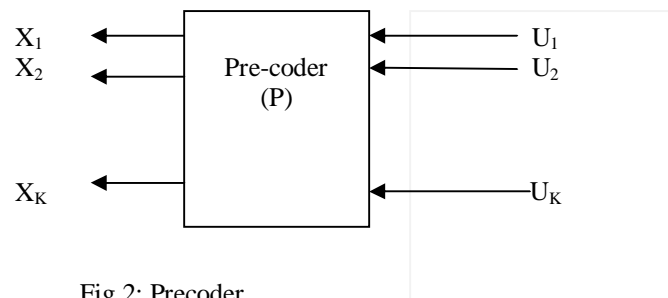
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discontinued users have no data transmission, their user data can be replaced by virtual signal to obtain precoder output equal to zero.



$$X=PU$$

Fig 2: Precoder

Thus the precoder coefficients can be recomputed for every symbol positions which is significant drain on energy and effectiveness on vectoring is maintained. The graph depicts energy consumption of the three vectoring approaches as function of target rate. Two traffic patterns are evaluated, in Traffic Pattern one (TP1) all 10 users require a common target rate. TP1 is heavy usage pattern. Traffic Pattern two (TP2) only 2 users require a common target rate. TP2 is light usage pattern. For TP1 analog power used with muted and discontinuous vectoring is similar to that of full vectoring. For muted vectoring decreased per symbol capacities leads to a significant number of occupied symbol positions and leads to higher power use. As in the case of discontinuous vectoring it can save power similar to full vectoring. In TP2 because of small number of users greatly increases the power saving potential on discontinuous line. Thus the discontinuous vectoring have slight power advantage over muted vectoring. [2].

STABLE SLEEP MODE OPTIMIZATION

This deals with optimize use of existing DSL low-power sleeping modes (L2 and L3) in order to improve the energy efficiency of DSL access networks [3]. Given that switching ON a DSL line can cause instability by increasing the amount of time varying crosstalk in the cable bundle, and that it takes energy and time to switch a DSL line ON and OFF. A simple "sleeping" policy would wake up a DSL line as soon as there are data to be transmitted and then put it to sleep when the transmission is over. Designing an optimal "sleeping policy is complex DSL lines sharing a cable binder crosstalk into each other, so switching DSL lines on and off generates time-varying crosstalk which can cause errors and instability since the lines receiving the crosstalk adapt at start-up assuming stationary noise. In this work, stability is related to time varying noise impact through crosstalk coupling. More specifically the larger the noise impact magnitude and variation, the more symbol errors occur, and as a result, the less stable DSL lines. Initially optimize the use of multiple heterogeneous link states, L0 (ON), L2, and L3. L0 mode corresponds to the DSL being fully ON and functional, L2 mode corresponds to the case where the transmit power is a small fraction of the power at L0, whereas L3 mode corresponds to the case where no signal is transmitted on the line L2 has a non-zero power consumption but a lower switching cost, whereas L3 has zero power consumption but a higher switching cost. Taking this tradeoff into account, we calculate the optimal thresholds for changing the sleeping state from L3 to L2 and vice versa. Fig. 1 shows the power consumption and switching cost incurred during transitions between the three different power states in DSL lines. We assume that each line has a finite buffer B and three heterogeneous modes of operation: ON mode (L0) and two sleeping modes (L2 and L3). The power that the line consumes when ON is P_{ON} , whereas the power consumption at L2 is P_{SL} , with $0 < P_{SL} < P_{ON}$. The power consumption at L3 is considered to be 0.

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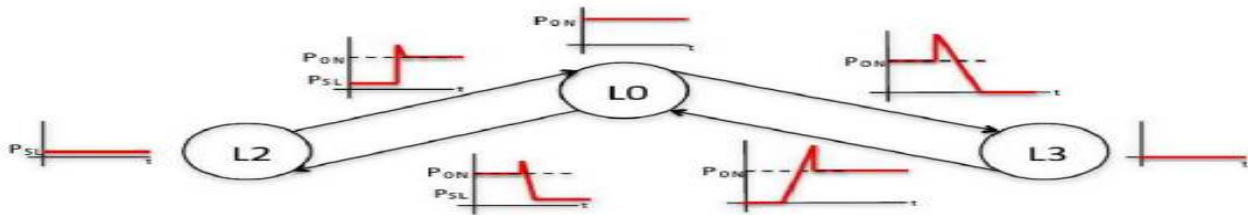


Fig 3: Transition between different power states [3]

The transmit rate in ON mode is R_{ON} , whereas the transmit rate at L2 and L3 is $R_{SL} > 0$ and 0 respectively. In order to simplify the analytic derivations we will assume that $R_{SL} \approx 0$ without loss of generality, given that $R_{SL} \ll R_{ON}$. The energy consumed in ON/L3 switching is E_{ch}^3 . The time required to wake up from L3 is τ_3 , whereas the time required to wake up from L2 is τ_2 , with $\tau_3 > \tau_2$. In addition, the cost from overhead signaling incurred during ON/L2 switching is expressed in terms of energy as E_{ch}^2 , with $E_{ch}^3 > E_{ch}^2$. In order to make the problem analytically tractable we neglect transitions between L2 and L3. The switching cost includes the energy cost incurred everytime the line switches from sleeping mode (L2 or L3) to ON and vice versa. It also includes the time it takes for the line to wake up from L2 or L3, which we express in terms of the $\lambda\tau_2$ or $\lambda\tau_3$ jobs that accumulate in the buffer during the line wakeup process. We find the policies that result in a Pareto optimal tradeoff between energy consumption and average delay, taking into account the switching cost consumed every time there is an ON to OFF or OFF to ON switching, with OFF mode corresponding to L2 or L3. Here we take into account the time it takes for the line to wake up. During the wake up process, jobs are being accumulated in the buffer, thus causing an average increase of $\lambda\tau_2$ or $\lambda\tau_3$ jobs in the queue length. Energy is saved by reducing the number of times we expend the energy E_{ch}^2 or E_{ch}^3 required to switch on the line or turn it off to L2 or L3. The introduction of L0-L2/L3 mode coordination results in time-varying crosstalk, which can lower the SNR margin of the M uncoordinated lines sufficiently to cause them to retrain, adversely impacting stability. We study the effect of varying sleep modes on the uncoordinated lines only, because stability is guaranteed for coordinated lines by design. A precise definition of stability is not straightforward and depends on many DSL implementation issues. Generally, if a line m undergoes an increase of crosstalk interference and noise that is larger than the noise margin, it might become unstable. The introduction of sleeping modes for coordinated DSLs results in an increased noise impact on the uncoordinated lines. To improve the stability behavior of the DSL network when DSLs are allowed to switch to sleeping mode, we propose a temporal dimension solution, where the wake-up of a DSL from L2/L3 to ON occurs gradually following some increasing time *function* instead of being a step function, and can be implemented by discrete, intermediate power management states, or (L2 sub-modes) with fixed time intervals equal to the wake up time, e.g., $w_n k \in \{0, 1/8, 1/4, 1/2, 1\}$, $\forall k, \forall n \in \mathbb{N}$. Note that if, for example, the optimal sleeping mode is L3 and there are i L2 sub-modes, then the actual number of modes incurred during an $L3 \rightarrow ON$ switching is $i + 2$, including the L3 and ON modes. Fig. 4 shows the improvement of the averaged (across all uncoordinated lines) maximum noise impact when the number of L2 sub-modes increases. Note that the maximum noise impact per tone is important, as violating the noise impact on a tone of one line can result in errors. Finally, Fig. 5 shows the energy savings achieved by both the optimal sleeping policy and a baseline policy that turns a line on as soon as there is 1 job waiting in the queue to be processed.

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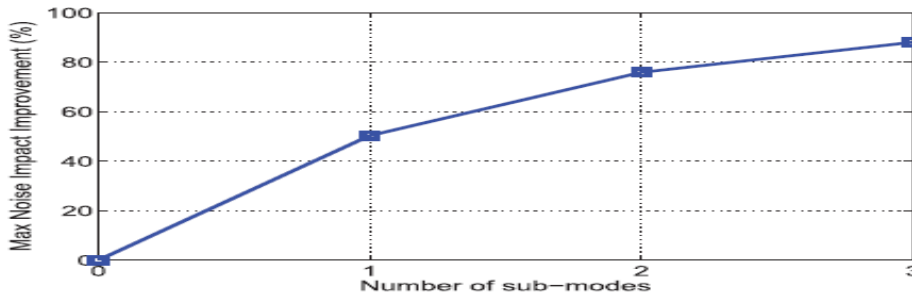


Fig 4: Maximum Noise Impact Improvement Graph

The energy savings are averaged across all lines. For all traffic loads considered, the optimal policy performs better than the baseline policy. The gap between these two policies is higher for lower traffic load, which corresponds to the realistic scenario of underutilized DSLs. Our optimal policy results in significant energy savings for lower traffic loads, i.e, around 85% for traffic load 10% and 50% for traffic load 20%. Naturally, the energy savings decrease as the traffic load becomes higher, which reduces the lines' sleeping times. [4]

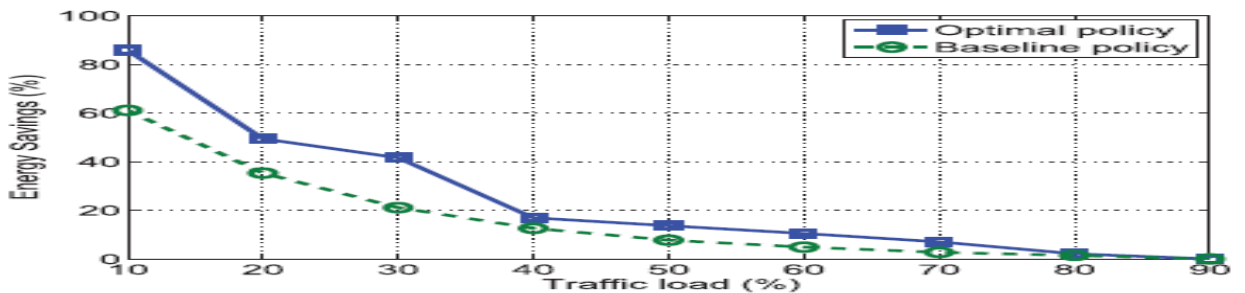


Fig 5: Energy Saving Graph

DYNAMIC RESOURCE ALLOCATION

Linear matrix precoding, also known as vectoring, is a well-known technique to mitigate multiuser interference in the downlink digital subscriber line (DSL) transmission. While effective in canceling interference, vectoring does incur major communication frame, resulting in significant energy consumption when the number of lines is large overhead and computational overhead in terms of the transmission of idle symbols and precoder-data multiplications at each data. InG.fast, there are basically three kinds of symbols: data symbols during which actual data is transmitted, idle symbols during which no data is transmitted but the transceiver is still working, quiet symbols during which the transceiver is turned off. To save transmit power, the number of idle symbols should be as small as possible. An example is shown in Figure 6, where each square represents one symbol position and there are six lines and fourteen symbol positions in the data frame. Let d_i be the number of transmission opportunities, then $d_1 = 10$, $d_2 = 11$. In this example, seven idle symbols are inserted. Besides inserted idle symbols, another source of major power consumption is the vector processing step where the data matrix X (see Figure 6) is multiplied by the precoder matrix P during the transmission of each data frame. This precoder-data matrix multiplication incurs significant energy consumption when the number of lines is large. With the introduction of DO, each data frame is further divided into two transmission intervals: a Normal Operating Interval (NOI) and a Discontinuous Operating Interval (DOI). In the NOI, all lines are involved in a common vectoring group. In the DOI, the lines with remaining untransmitted data symbols are grouped into non-overlapping subgroups, and vector processing is performed within each subgroup so that crosstalk cancellation is maintained among the members in each subgroup

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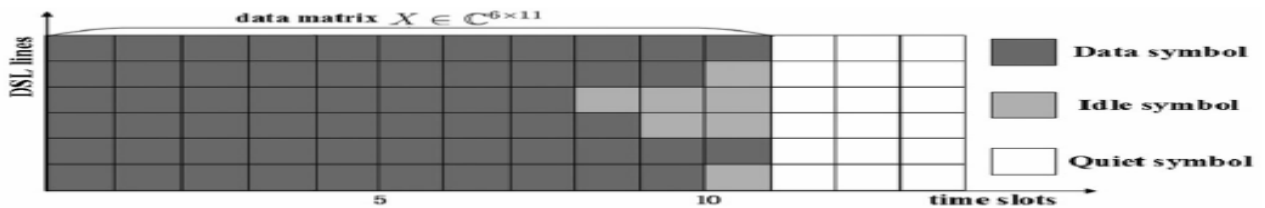


Fig: 6 A Data Frame With Only NOI

To eliminate cross-subgroup interference, the data transmission in the DOI is arranged in a TDMA (Time Division Multiple Access) manner. A feasible DO scheme of the case in Figure 6 is given in Figure 7 the first eight time slots constitute NOI during which all six lines are vectored together, the remaining six time slots constitute DOI during which the transmission of the three subgroups are scheduled in sequence. In this way, no idle symbols are needed in the transmission of user data in this data frame. Furthermore, notice that the precoder matrix for each subgroup has a smaller size than that of the large precoder used in NOI for all the lines. Thus, the total computation cost of the precoder data matrix multiplications in NOI and all subgroups is smaller than what would be required if all lines are vectored in a single group. In this way, the energy efficiency is significantly improved. In the examples considered above (Figures 6 and 7), the effect of DO is obvious. Without DO, vectoring requires seven idle symbols and multiplying the precoder $P_0 \in C^{6 \times 6}$ with the data matrix $X \in C^{6 \times 11}$. In contrast, using the DO strategy described in Figure 7, no idle symbols are needed; moreover the number of multiplications is reduced: multiply $P_0 \in C^{6 \times 6}$ with the data matrix $X_0 \in C^{6 \times 8}$ during NOI, and multiply the precoder $P_1 \in C^{2 \times 2}$ with the data matrix $X_1 \in C^{2 \times 3}$ in subgroup 1 of DOI, the precoder $P_2 \in C^{2 \times 2}$ with the data matrix $X_2 \in C^{2 \times 2}$ in subgroup 2, the precoder $P_3 \in C$ with the data matrix $X_3 \in C$ in subgroup 3. Since multiplying $n \times n$ with $n \times m$ complex matrices requires $4n^2m$ scalar multiplications, the number of scalar multiplications is reduced from 1584 to 1236 with the introduction of DO.

DESIGN AND ADJUSTMENT OF DO SCHEME

For frames with different demands, the optimal DO patterns (in the sense of having the minimum energy in vectoring) will be different. In this paper, the author pointed out that DO pattern refers to the parameters that fully describe the DO scheme are the duration of NOI, the grouping strategy in DOI, and the transmission duration of each subgroup in DOI. To design DO transmission, we need to consider several issues:

- 1) Given the number of data symbols of all lines, partition the frame as NOI and DOI;
- 2) Assign each line with remaining untransmitted data symbols to a subgroup;
- 3) Arrange the transmission interval for each subgroup in DOI in a TDMA manner.[5]

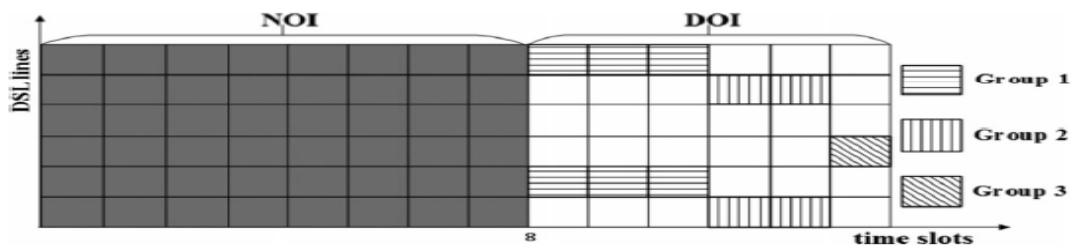


Fig 7: A Feasible DO Scheme

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III. PERFORMANCE COMPARISON

The detailed comparison chart based on different techniques which were studied for energy efficient transmission in DSL is shown in Table 1. The parameters which used are crosstalk, computational complexity and efficiency. First we discuss on the parameter crosstalk, how it will effect in each techniques. In discontinuous operation it is mainly due to the approximation of the precoder. The noise in the receiver will comprises of additive noise and crosstalk interference from the active users. Vectoring is used in order to cancel the crosstalk by generating precompensation signals which is antinoise signals. Mainly two types of vectoring is performed which is muted vectoring and discontinuous vectoring. In muted vectoring simply set precoder output to zero, that allows analog power but the effectiveness of vectoring is lost. Thus there exists crosstalk between active users. As in the case of Stable sleep mode optimization Due to Introduction of L0-L2/L3 modes coordination results in time-varying crosstalk, which can lower the SNR margin of the M uncoordinated lines sufficiently to cause them to retrain, adversely impacting stability. We study the effect of varying sleep modes on the uncoordinated lines only, because stability is guaranteed for coordinated lines by design. A precise definition of stability is not straightforward and depends on many DSL implementation issues. Generally, if a line m undergoes an increase of crosstalk interference and noise that is larger than the noise margin it might become unstable. The author defines the noise impact as a stability measure, which represents the impact on the uncoordinated lines caused by the L2/L3-ON transitions of the coordinated lines. Dynamic resource allocation, all lines are involved in a common vectoring group in NOI and In the DOI, the lines with remaining untransmitted data symbols are grouped into non-overlapping subgroups, and-vector processing is performed within each subgroup so that crosstalk cancellation is maintained among the members in each subgroup. To eliminate cross-subgroup interference, the data transmission in the DOI is arranged in a TDMA (Time Division Multiple Access) manner. Thus the precoder needed for the computation purpose is small in size as compared to G.fast. In a simple way we can conclude that it is mainly due to the approximation of precoder. Next parameter which considered for comparison is computational complexity. In G.fast, precoder coefficients want to be recomputed for every symbol positions when discontinuous vectoring are used. In muted vectoring the effectiveness of vectoring is lost when precoder output tends to zero thus there is no need for precoder coefficients computations, reducing complexity. In stable sleep To improve the stability behavior of the DSL network when DSLs are allowed to switch to sleeping mode, we propose a temporal dimension solution, where the wake-up of a DSL from L2/L3 to ON occurs gradually following some increasing time function instead of being a step function, and can be implemented by discrete, intermediate power management states, or (L2 sub-modes) with fixed time intervals equal to the wake up time. Due to these intermediate power states computation become complex. In third method the precoder matrix for each subgroup has a smaller size than that of the large precoder used in NOI for all the lines. Thus, the total computation complexity of the precoder data matrix multiplications in NOI and all subgroups is smaller than what would be required if all lines are vectored in a single group. The efficiency is compared for the three techniques and is found that using dynamic resource allocation is more suitable for energy efficient transmission purpose in DSL.

Techniques	Crosstalk	Computational Complexity	Efficiency
Discontinuous Operation	HIGH	HIGH	LESS
Stable sleep mode optimization	MEDIUM	MEDIUM	MEDIUM
Dynamic resource allocation	LESS	LESS	HIGH

Table 1: Comparison Chart

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IV. CONCLUSION

The three mechanisms, Discontinues operation, Stable sleep mode optimization and Dynamic Resource Allocation is studied in this survey. The benefits of these three mechanism are evaluated by numerical simulation results, demonstrating a three-way tradeoff between crosstalk, computational complexity and efficiency. The third technique, Dynamic resource allocation provides higher efficiency with negligible crosstalk and computational complexity thus suitable for transmission purpose in DSL.

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