Dynamic line management combined with DSL innovations

A win-win solution for subscribers and service providers

DSL service providers need to deliver speed, quality and reliability to their residential subscribers. They must also find cost-effective ways to limit field interventions and copper replacements. And, in an environment of intense competition, they need to provide superior quality of experience, to reduce customer complaints and limit churn. Dynamic line management combined with DSL innovations provides a win-win solution for service providers and subscribers.
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Introduction

Our homes have gone digital. We stream music, watch HD TV, bank online, work from home, use instant messaging (IM) and share our photos in the cloud.

To share and remotely store all this digital content, we need excellent Internet service. We require speed, quality and reliability from our Internet connection. Speed, so we can enjoy digital content on several home devices. Quality, so we get a proper multimedia experience. Reliability, to ensure no service interruptions during remote conferencing or while watching our favorite sports.

As shown in Figure 1, DSL (copper) remains the most popular broadband connection type worldwide, ahead of fiber-to-the premises (FTTP) and cable. According to Infonetics, this trend is expected to continue until at least 2018 [1].

Figure 1. Broadband connections by access type

For service providers, DSL is cost-efficient and provides the required bandwidth for the services and content consumers want. However, there are also challenges, ranging from physical impairments such as oxidized connections or lack of insulation to modem software issues. There is also the possibility of suboptimal do-it-yourself (DIY) installation, hazardous cabling or surrounding electromagnetic pollution. All of these scenarios can degrade communications.

To validate the copper business model, service providers need to provide subscribers the speed, quality and reliability they demand while limiting field interventions and copper replacements. They also need to implement service package upgrades in a controlled, safe and cost-effective way.
The solution is to invest in the latest DSL innovations and also perform dynamic line management (DLM). With DLM, each copper connection is optimized, guaranteeing each subscriber the highest feasible speeds along with the required quality and reliability—and, ultimately, a better experience. Service providers benefit from cost-effective use of the existing copper network and less subscriber churn. Consequently, DLM is a win-win solution that benefits both subscribers and service providers.

The customer experience matters

Customer experience has become a top priority: Gartner describes customer experience innovation as “the next frontier” [2].

Speed matters to subscribers (see Figure 2). They want fast Internet surfing and HD multimedia content through IPTV or from over-the-top (OTT) providers. They also want remote video conferencing and desktop sharing as well as to share photos with friends and store photos in the cloud. All of this digital content consumes ever more bandwidth, which service providers had better be able to deliver.

Figure 2. Importance of speed, reliability and quality of experience

Our homes are now connected to the outside world not just through desktop computers but also by laptops, smartphones, tablets and maybe even “home cloud” network attached storage (NAS) to stream and share multimedia content toward the Internet. Some subscribers also have Voice over IP (VoIP) stations, security systems and audio amplifiers. The number of connected devices continues to increase: Strategy Analytics forecasts that by 2020, there will be 4.3 Internet-connected devices for every person on the planet [3].

All of these devices consume content and are upgraded remotely. Subscribers do not want to wait hours for that, so it’s vital that their Internet is fast.
“We’ve entered the age of the customer—an era when focusing on customers is more important than any other strategic imperative.”
Forrester, 2015 [4]

Subscribers also demand reliable Internet. If service interruptions occur at all, or even worse, regularly, it’s annoying because none of the connected devices can exchange data with the outside world. This means the music stream gets interrupted, the remote conferencing stops, the data stored in the cloud is not accessible, IPTV service is not available, and users do not even have access to email. Repetitive service interruptions can trigger customer complaints or even a change of service provider.

Quality of experience (QoE) is vitally important. If voice sessions are affected by noise or lags, or if video regularly freezes or suffers from pixelization, subscribers perceive the level of quality as low, not offering a suitable experience. The same degradation of QoE can also occur during Internet surfing (for example, during file transfer). Even if the speed is reduced only transiently, if this happens often, customer complaints increase significantly and customers may also change their service provider.

For service providers, who must consider all these aspects of the customer experience, managing the customer experience is critical.

Copper is still viable

To meet service level agreements (SLAs) with subscribers, service providers must provide a high level of service. Fierce competition among service providers also forces them to constantly look for ways to improve service.

Changing the DSL (copper) infrastructure to another medium, such as FTTP, is an option. However, this is not convenient because it usually involves civil works (such as construction on public roads to lay fiber-optic cable) and may also include installation at the subscriber premises. It’s also expensive to evolve to a full-fiber access network. Moreover, even if there is a need for speed and quality, fiber is usually not required to the home.

Instead, the latest copper technologies, such as vectoring, Vplus and G.fast, can provide bandwidth that is comparable to fiber offers. As a result, investing in copper technologies remains relevant, convenient and competitive for the service provider and also meets subscriber demands.

These technologies are described in more detail in the section Leveraging innovative DSL technologies.
Admittedly, copper is a sensitive medium easily affected by the environment\(^2\), and corruption of the transmitted data can occur regularly. The result is lower QoE for customers. However, there are techniques that can be used with most of the innovative copper technologies to recover from data corruption and improve robustness. Examples include:

- Power management
- Optimizing the signal-to-noise ratio (SNR) margins
- Changing the data rate through seamless rate adaptation (SRA)
- Employing cross-interleaved Reed-Solomon code (CIRC) for error detection and correction
- Using G.inp to recover from errors, retransmit data and reduce latency

All these techniques, widely deployed in the networks of major service providers, allow them to offer ultra-broadband service.

**Configuration considerations**

Each DSL link is unique, including its location, the surrounding devices and the presence-or absence-of neighboring lines. Each copper pair is also unique: lengths vary and so do characteristics. Connectors vary or are located at different sites. All of these factors can affect data transmission differently from loop to loop.

At the customer premises, there can be even wider differences. Some sites use twisted and shielded cables while others use unshielded flat cables. The customer premises equipment (CPE)—in this case, modems—may be different, or at least running different software versions. If the plain old telephone service/public switched telephone network (POTS/PSTN) is still active, some end users may not have correctly connected a splitter.

The usage of each Internet connection also differs. Some subscribers are streaming multimedia while others are simply surfing the Internet. Some pay for high bandwidth while others do not.

Despite all these differences, service providers usually do not make distinctions among customers who subscribe to similar services. Instead, the customers are treated as a group, given generic configurations and provisioned with similar profiles.

The generic configurations usually do not fit for every line in the group because of all the differences in environment, CPE and subscriber usage already described. For example, a subscriber with high-quality shielded cables does not require the same amount of protection as a subscriber who has unshielded flat cables.

\(^2\) For example, copper pairs are can suffer from electro-magnetic interference.
Service providers’ configuration strategies also differ. A conservative provider will choose a strategy based on service reliability. In this situation, each customer benefits from a mandatory amount of protection, typically high. By contrast, another provider may take the risk of limiting reliability in favor of performance: higher speed or lower latency. In either situation, a balance between reliability and performance must be found and dedicated to each line.

Using the service reliability strategy has a cost, for most subscribers, in terms of performance. The service provider is prevented from offering the highest bandwidth to the majority of the subscribers to, apparently, gain in safety. With the performance strategy, there is a significant risk for subscribers in terms of service reliability as well as QoE degradation.

For service providers, the two strategies present an apparent contradiction. Providers want to invest in technologies that allow them to reach higher bandwidths. However, they also want to limit bandwidth to potentially gain in reliability. Dynamic line management combined with innovative DSL technologies solves the apparent contradiction.

Figure 3 shows the gains service providers can achieve using DLM instead of a strategy based on only speed or robustness.

**Figure 3. Comparison of DLM and non-DLM strategies**

![Figure 3](image-url)
Dynamic line management

Service providers wanting to offer the highest feasible bandwidth to fit each end-user subscription and also guarantee reliability and high QoE need a dedicated configuration for each line. Dynamic line management provides automatic line reconfiguration, ensuring that the best profile configuration is assigned to the line to provide the subscribed level of service. DLM also provides automated testing, diagnosis and optimization of each DSL link to ensure the optimal balance between robustness and performance. Whatever bandwidth, correction mechanisms, compensation or retransmission techniques are deployed, DLM combines them in the most appropriate way to maximize each subscriber experience.

Finding, for each line, the optimal set of parameters that will provide the highest level of satisfaction for the subscriber requires a dynamic method. This is because, after copper pairs are deployed, they can be reassigned or extended. The CPE can also be upgraded, and copper technologies evolve.

The copper pair itself is also not static: it is sensitive to various events. Usual home activities, such as using electronic devices, turning on lights, and even using microwaves or vacuum cleaners can influence the DSL service. During the weekends, these activities may be extended. Neighbors’ DSL usage and subscriber location can also interfere with the line. More random phenomena, such as weather, the vacations and some events (for example, World Cup soccer every four years) can also influence the line and therefore the communication quality. There is a need for a dynamic method able to assess and adapt to all of these evolving conditions.

Because line behavior is influenced by many unpredictable factors, modeling is not feasible. Even if daily patterns could be extrapolated, it is difficult to infer their potential consequences on Internet service. Also, subscribers use a variety of DSL technologies, which further complicates modeling.

Dynamic line management provides automated testing and diagnosis of each DSL using quality of service indicators derived from errors occurring during data transmission. DLM evaluates data related to speed, reliability, stability and degradations, including transient degradations, then automatically optimizes each line.

Some actions are intended to boost the speed, if feasible. Others are intended to enhance the stability or service quality. Some actions may improve speed as well as service quality and stability, depending on what is needed and feasible.

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3 When people go away for vacations, they often turn off their CPE, then turn it back on when they return. This can cause power noise patterns that affect neighboring lines. During events such as World Cup soccer, all subscribers may turn on their CPE at the same time, increasing the amount of power and therefore noise in the network.
It may be surprising to learn that, to boost speed, changing the DSL data rate (with or without SRA) is not always required. In some cases, if the service is impacted, CIRC can be used for error detection and correction; this can even lead to enhanced end-user speed.

Even more surprising, reducing the DSL data rate may actually increase speed. Improving the robustness of the link, for example by raising the SNR margins, can be implemented by limiting the DSL data rate. The link becomes less sensitive to potential causes of data corruption. The rate of corrupted symbols is lowered, so the amount of retransmission of corrupted packets requested by upper protocol layers (such as TCP/IP) is limited. Transmitting less – but correct – data per second provides higher speed and a better experience than transmitting more data that is corrupted and therefore needs to be retransmitted.

**Leveraging innovative DSL technologies**

Requirements for bandwidth and service have challenged DSL manufacturers to implement new technologies and mechanisms to boost performance as well as to reduce or compensate for transmission errors.

With vectoring, reaching speeds of 150+ Mb/s is realistic. Vplus provides speeds of 300 Mb/s. With G.fast, the “magic number” of 1 Gb/s can be achieved using the copper pair.

With G.inp, data gets retransmitted at the physical layer. With SRA, speed can get boosted without interrupting the service. With bonding, several copper pairs are used to enhance the bandwidth to twice the speed.

However, some questions remain. Is the bandwidth guaranteed over time? Is the service reliability and quality high enough for the requested content? Is the configuration suitable for each pair? Are the subscriber experience and level of satisfaction high? Are the number of customer complaints or field interventions reduced? Is a field intervention necessary, suitable or enough to restore high bandwidth and provide a good experience? As service provider, how can I limit them?

Service providers invest in vectored technologies so they can offer higher bandwidth. Vectoring cancels crosstalk, reducing the noise level, enhancing the SNR and allowing a higher bitrate. A side effect of noise cancellation is to make the link more sensitive to environmental noise and electromagnetic interference. The presence of repetitive impulse noise or patterns of varying alien noise become obvious, affecting the stability of the DSL and degrading its quality.
Using CIRC and G.inp error compensation/retransmission mechanisms help to improve service quality by reducing or compensating for errors. However, transient loss of throughput can be introduced because of excessive retransmissions, affecting, for example, a video stream. Excessive amounts of correction or interleaving are usually also not desired because they can constantly affect the speed and add latency.

To guarantee that the level of protection/compensation is suitable for each link, and also to not introduce undesired consequences due to over-estimated protection/compensation, DLM is required. Most investments in new DSL technologies have been made to improve speed, so DLM is challenged to make the best use of the capabilities of each technology to provide the highest speed together with maximized end-user QoE.

Seamless rate adaptation dramatically boosts the speed while the line is in service. This prevents losing bitrate by limiting the amount of residual SNR margins. However, was the margin necessary to guarantee high robustness? What if a sudden safety reduction leads to stability or quality degradation while subscribers are watching their favorite movies? Is quality of service controlled and therefore guaranteed while taking such actions? For how long will degradation last, and could it become repetitive? Because SRA does not evaluate the service quality before boosting the bitrate, all these questions are valid.

With DLM, fixed or seamless bitrate increases are allowed if there is no impact on the service quality. The amount of increase is therefore controlled to stay on the safe side. More generally, DLM leverages the benefits of SRA or other innovative mechanisms (for example, G.inp) to guarantee good reliability, stability and quality for each subscriber. This is accomplished by continuously tracking the quality of service and by managing all the DSL mechanisms.

Benefits for subscribers and service providers

Speed, quality and reliability are key to subscriber satisfaction. Combining DLM with DSL innovations provides the highest feasible speed from each Internet access line while guaranteeing good QoE and high reliability. In practice, this means achieving the highest speed by limiting the number of errors or retransmissions; raising the QoE by limiting the amount of lag, jitter and artifacts; and increasing reliability by avoiding modem resynchronization, which interrupts service.
Subscribers also benefit from continuous care of their line and service. If the infrastructure changes, for example because of in-house cabling upgrade, the line will automatically be reconfigured to take advantage of the new infrastructure. If civil works in the neighborhood have the potential to disrupt DSL communication, the line will automatically be reconfigured to protect against external disruptions.

The combination of DLM and DSL innovations provides subscribers with proactive maintenance that makes the best use of each DSL and maintains high quality and reliability. Continuous assessment of service quality ensures that if reconfigurations do not provide the required service quality and reliability, the service provider will be notified, and can provide field intervention.

For service providers, DLM optimization of each line makes the best use of the deployed DSL technologies while guaranteeing a high level of service to subscribers. From a troubleshooting process perspective, DLM proactively solves many subscriber issues by leveraging the various DSL mechanisms available. If severe degradations cannot be resolved through automatic reconfiguration, DLM efficiently identifies the problem.

The end results are fewer customer complaints and less field intervention (fewer truck-rolls), leading to reduced operating expenses. Boosting bandwidth in a safe and reliable way satisfies subscribers, which helps to retain customers and reduce churn.

Opting for the Dynamic Line Management solution as a feature of the Nokia Network Analyzer product helps service providers ensure that DSLs meet quality and stability requirements for the successful deployment of high-speed Internet and triple play services. Nokia Network Analyzer-Copper (NA-C) supports operational best practices throughout the life cycle of the access lines, including planning, prequalification, provisioning, maintenance, troubleshooting, and customer support.

For more information about Nokia NA-C, go to:
Acronyms

CPE        customer premises equipment
DLM        dynamic line management
DSL        digital subscriber line
NAS        networks attached storage
QoE        quality of experience
SNR        signal-to-noise ratio
SRA        seamless rate adaptation

References


