Domos White Paper: Wi-Fi Slicing

The State of Wi-Fi

Fixing Wi-Fi issues used to be about extending coverage, i.e. getting access to the signal. We still intuitively evaluate Wi-Fi quality on the signal strength. Over the last years there has been tremendous progress in getting coverage across every corner of the home, especially with the deployment of mesh and roaming technologies. Today, coverage is no longer a dominant Wi-Fi issue.

Wi-Fi Mesh = building the road network to access everywhere

*Wi-Fi Slicing = policing and control to avoid congestion*

Now, with every device in every corner connected to the internet, we run into a different type of problem - congestion. Congestion is not solved by stronger signals or better coverage. The solution lies in optimising resource orchestration and requires real-time control, management and prioritisation. This is what Domos addresses with its Wi-Fi Slicing technology.

In congested networks, just like on congested roads, we get queues. Queues induce latency. High latency reduces Quality of Experience (QoE), especially for real time sensitive use cases like video conference and online gaming, but also streaming quality is adversely affected.

Wi-Fi impact on end-to-end QoE

Through commercial deployments and research projects, Domos has been able to actively probe latency in thousands of homes over several years, aggregating huge volumes of unique training data sets. Overall the data prove how Wi-Fi adversely impacts the end-to-end quality of experience by introducing variability and instability into overall network latency. The graph below shows the typical

observed end-to-end latency, where the blue component is latency to the internet and yellow is latency as probed by us over the Wi-Fi network. The sum of both is the overall latency as experienced by the end user.
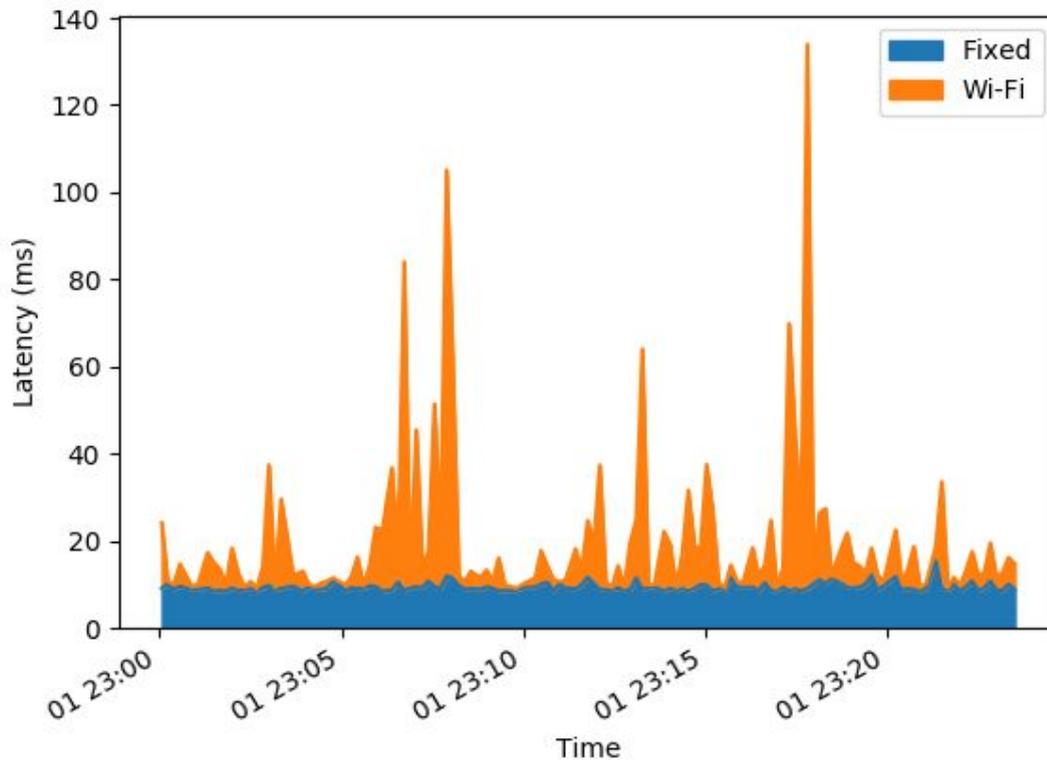
In the Broadband Forum we work with Vodafone, Orange, and others to establish QED[1], a new network quality metric that captures this stochastic variability into a statistical distribution. In this framework we can model directly how much latency and variation that each use case can handle before the end user will perceive reduced QoE.

For more detail and data on Wi-Fi, please read the separate white paper going deeper into QED and how it is an enabler of Wi-Fi Slicing[2].

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[1] https://www.broadband-forum.org/open-broadband/broadband-experience
[2] http://www.domos.no/qed-white-paper

What is Wi-Fi Slicing?

Wi-Fi Slicing is a service that understands precisely what is needed from the network to make each application work perfectly. It works automatically and autonomously. It reacts immediately when an application has started and can take action as needed on the network to make sure the application works as expected. It knows what is the root cause of the problem, and what can fix it.

Domos Wi-Fi Slicing solution consists of several advanced machine learning algorithms, all pre-trained by Domos and deployed and executed as a standalone software module on the Wi-Fi router (CPE):

Traffic Classification and Application Detection

The network flow classifier algorithm can classify traffic into general categories like separating Queue-Building from Non-Queue-Building flows. Additionally it can be trained to detect specific application signatures, leveraging a library of digital fingerprints identified and maintained by Domos. The digital fingerprint is composed of a collection of easily available features like the TCP/IP 5-Tuple and the initial packet size sequence.

Through the extensive pre-training of these digital fingerprints, the real time Traffic Classification and Application Detection can be implemented in a compute efficient C5.0 decision tree algorithm, allowing for wide portability to legacy CPEs.

Quality of Experience (QoE) Prediction

Domos actively probes latency in large volumes of residential Wi-Fi networks, providing unique training datasets for training machine learning models to predict the network link quality from features that are passively observed on the radio interface (radio and traffic data). These datasets are used to train deep neural network (DNN) algorithms that can predict QoE violations before they occur. The DNN algorithms use standard network data as features and can continuously monitor the Wi-Fi network when deployed on the CPE.

Issue Classification

When the QoE prediction indicates a QoE violation for one of the active applications, the Issue Classifier is activated to identify the probable cause(s). The classifier is pre-trained on massive amounts of actively probed datasets and is implemented in a C5.0 decision tree model consuming very limited compute resources. This implementation model makes the algorithm extremely versatile and adaptable to most legacy CPEs.

Optimisation for Application Outcomes

Optimisation for Application Outcomes algorithm allocates network resources to each flow. It maps the respective QoS requirement for each app to the overall network capability and quantifies the potential QoE impact of optimisation of radio and traffic configuration. The algorithm will also recognise stated preferences made by the network owner (example is "prioritise my work meeting" etc). Based on all these inputs, the algorithm optimises the network for each application outcome, according to the specific environment and specific preference in each home.
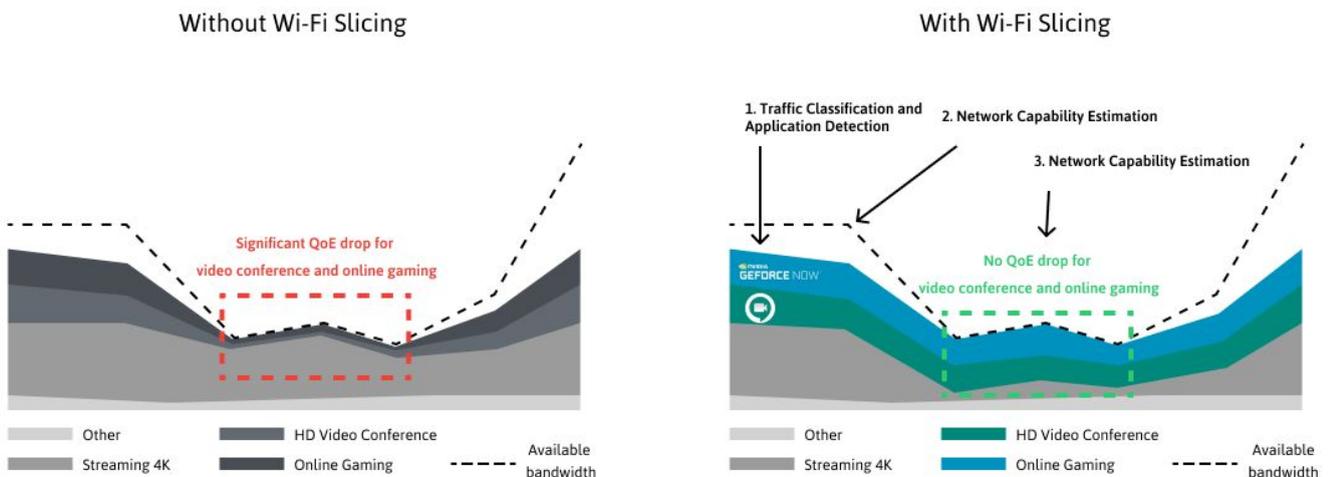
What about Privacy and Net Neutrality?

Privacy

Domos Wi-Fi Slicing is implemented as pre-trained machine learning algorithms that are executed autonomously and in real time on the CPE. No privacy sensitive data ever needs to leave the home, effectively eliminating privacy concerns. For improving the models, Domos only extracts fully anonymised "corner case" data sets, i.e. when the predictors and classifiers algorithms failed.

Net Neutrality

Wi-Fi Slicing is a technology that enables prioritisation of specific applications over others on the home Wi-Fi. We recommend that the service provider implement the technology under a policy that respects the preferences and control of the end user. The goal is to make Wi-Fi easier and better for the end user.

We have verified with lawyers in multiple European Net Neutrality compliant countries that

Domos Wi-Fi Slicing adheres to these principles:

- Domos Wi-Fi Slicing only prioritises within the home.
- Any application provider is free to provide their signatures and QoS requirement to Domos. Domos will make it possible for the end-user to slice the Wi-Fi for that specific application..
- The end-user should be able to choose what applications to slice the Wi-Fi for.

How to deploy Wi-Fi Slicing

The QoE Issue Classifier is built very lightweight so it can be deployed on most legacy CPEs. It only requires 200kB - 500kB RAM and can adapt to limited CPU capacity. The module supports most Linux-based middlewares, but we also have deployments on other platforms (like Broadcom eCos).

For the real time application detection, QED estimation and optimisation for application outcome modules, we recommend to deploy on containerised middleware platforms. The need for frequent updating of digital signatures and algorithm parameters means it typically will exceed the capacity of traditional device management systems. Most CPE vendors now have container support established or in their roadmaps. Domos supports a variety of middleware platforms and industry standards used by these vendors, including LXC, Docker and USP extension.

The modules can be configured using the industry standard protocols and data models from Broadband Forum (TR-x69, TR-181, TR-232). The CSP can also extract insight and outcomes directly through a REST API directly on the CPE.

Use Cases

Home Office / Video Conferencing

Working From Home makes the home Wi-Fi critical infrastructure for internal and external meetings and collaboration. With Wi-FI Slicing, team leaders, IT-managers and remote workers can have a shared dashboard to understand who has connection issues, the effect on video conferencing quality and how to solve it. Some issues can be solved autonomously or remotely by admins, while other issues might require actions in the employees home setup.

Streaming Video On Demand / IPTV

Streaming Video On Demand (SVOD) market is very competitive with OTT offerings and internet companies competing fiercely with the CSP traditional IPTV offerings. Consumption of digital content is today no longer confined by the TV set and the set top box. Consumers expect content and quality on every screen, in every room.

With Wi-FI Slicing the CSP can secure perfect Quality of Experience of streaming and IPTV content to every screen in the home.

Cloud Gaming

Online gaming is notoriously latency sensitive. In Multiplayer Online Games and Esport, latency is a deadly disease. Now we see the emergence of cloud gaming, where gaming is streamed from a central server. From a network perspective, cloud gaming combines high data volume of video with the latency sensitivity of online gaming, creating a huge challenge for network Quality of Service.
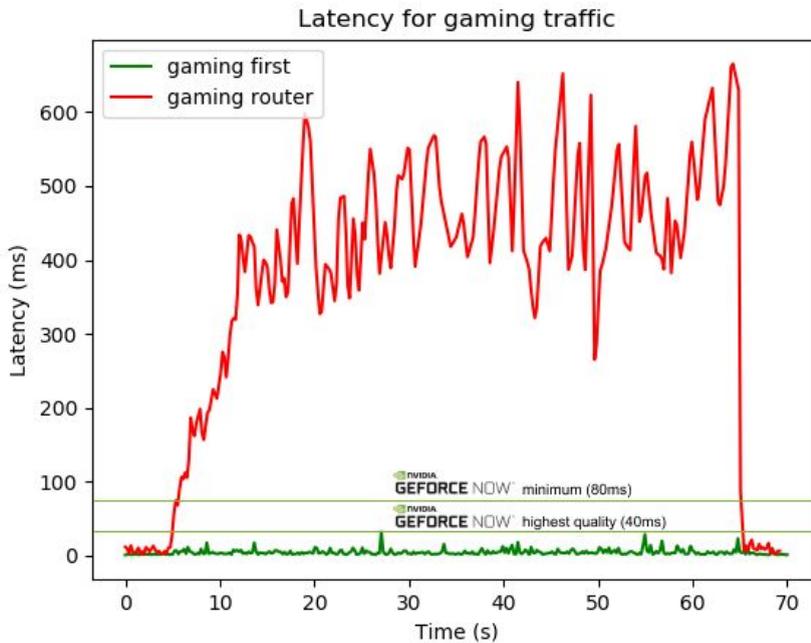
The graph above show how Wi-Fi Slicing installed on a standard CPE outperform a high end gaming router in a widely used network stress test environment[3].

Issue Classification

Most CSPs have established capabilities for issue classification and QoS controls through Wi-Fi management, ACS, OSS/BSS solutions etc. The QoE Issue Classification module of Wi-FI Slicing adds significant value to these solutions by adding real time issue detection and classification, without requiring active probing or other resource heavy and interfering actions.

Domos Issue Classification utilises passive probing for estimating the real time conditions, classifying issues and generating recommendations per home. The issues are made available to service assurance and customer care analysis through TR-x69 protocol from Broadband Forum, and can also be integrated as a REST API hosted on the CPE itself or on Domos-operated cloud. CSP can also configure policies to allow the module to execute selected recommendation types directly.

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[3] https://www.bufferbloat.net/projects/codel/wiki/RRUL_test_suite/

Licensing

Domos Wi-Fi Slicing machine learning algorithms are licensed to partners that help deploy on regular router/gateways.

More information about the benefits of licensing to our partners and how to become a Wi-Fi Slicing partner at https://www.domos.no/licensing or contact us at sales@domos.no