Fraunhofer FOKUS

WiBACK

Introducing Fraunhofer's Wireless Backhaul Technology

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An overview of the concepts and the current status (as of March 2014) regarding our ongoing R&D efforts

MOTIVATING WIBACK

Most rural areas throughout the world experience bad connectivity to the Internet. Companies suffer from inferior competitiveness and the population from digital exclusion. One of the reasons is the lack of technology to enable an appropriate business case for high-bandwidth service-provisioning in many deployment scenarios.

WiBACK is the result of several years of research and development at Fraunhofer FOKUS. It was motivated by the intention to provide carrier-grade service qualities for voice and data transmission over a large area with low-cost wireless technology. From a technological point of view, the WiBACK core can be positioned between point-to-point radio links and fibre-optic backbone networks. In its deployment, WiBACK is supplemented by access technologies such as Wi-Fi, GSM, UMTS or LTE, see Figure 1.

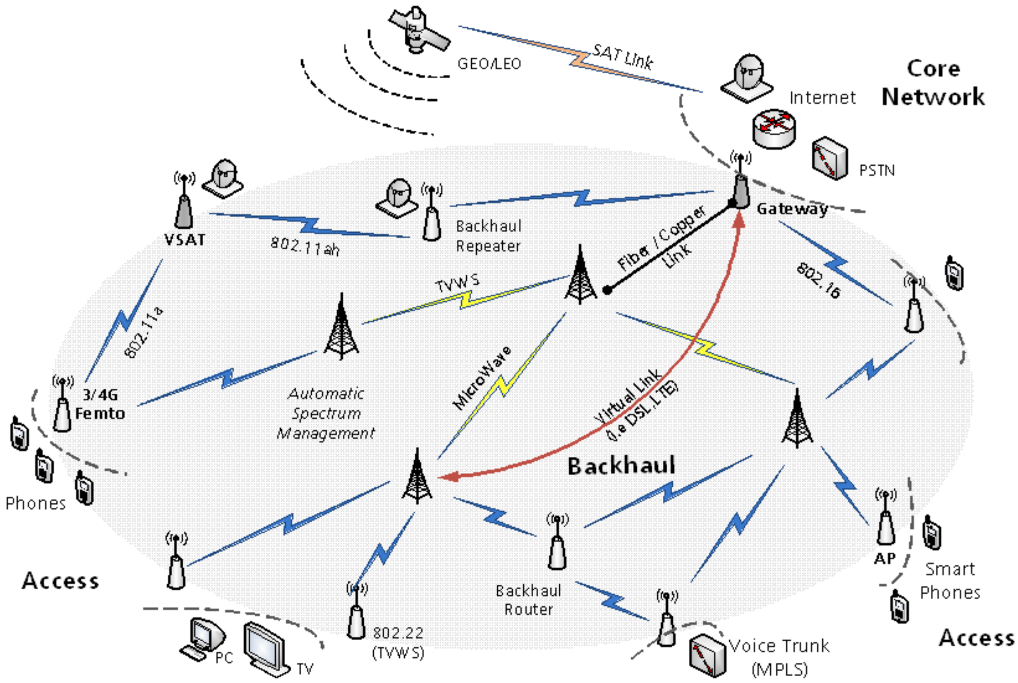

Figure 1- WiBACK bridges the gap between fixed infrastructure Back-Bone(Core) Networks and Access Networks. Edge Nodes such as Gateways (GW) and AccessPoints (AP) form the WiBACK interface to external networks.

Aiming at minimizing the CAPEX and, especially, the OPEX, WiBACK features a very low energy foot print as well as a self-managed, autonomous operation. This allows for solar-powered deployments and reduces the demand for trained personal, which is often lacking in developing rural areas.

WIBACK DEPLOYMENT SCENARIOS

In a typical deployment scenario, one or multiple WiBACK edge nodes connecting to a fixed and reliable network infrastructure are available. These can be provided by a commercial service provider or they can be interfaces to the existing network of an operator.

Located far from these edge nodes, multiple locations require high-quality connections to a voice or data network / the Internet. What "far" means depends on the local situation. In particular, the challenge cannot easily be solved by deploying a simple point-to-point radio-link or by digging cables into the ground.

Under such conditions, WiBACK serves as the backhauling technology to connect numerous user access points with fixed infrastructures.

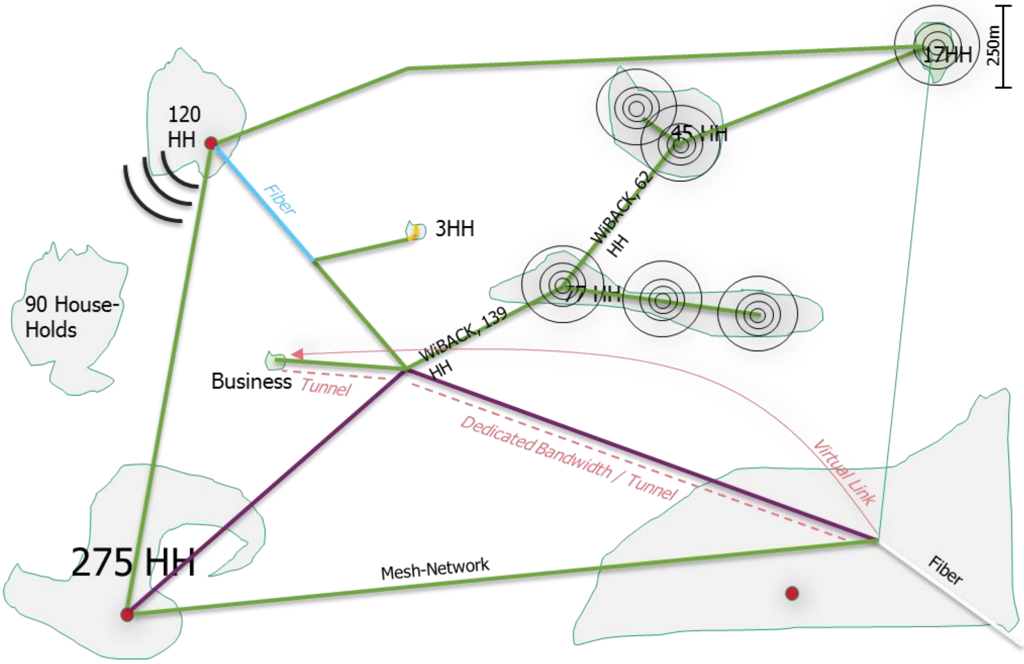

Figure 2: Typical WiBACK Deployment Scenario in Rural Areas

Examples for this deployment include temporary wireless networks for large events, rapid network deployment in disaster areas, broadband Internet services for rural areas, and wireless wide-area infrastructures in emerging regions.

Key features that make Fraunhofer's WiBACK technology unique are the combination of

- a wireless network that can span huge distances (several hundred km);
- provisioning of carrier-grade (guaranteed) service qualities for voice and data traffic;
- low capital expenditure (CAPEX) due to the use of commercial off-the-shelf hardware (typically IEEE 802.11 mass-market components with an optimized MAC Layer);
- low operational cost (OPEX) due to auto-configuration and self-management capabilities, as well as very low energy consumption;
- the possibility to run most nodes in the network on solar energy due to their energy efficient hardware and software, and the integrated charge controller.

WiBACK can be used to complement existing operator networks, but may also be deployed as a cost-effective low-energy alternative to conventional backhaul networks. To that end, WiBACK provides transparent IEEE802.3 Ethernet bridging incl. IEEE8021.q VLAN trunking between Edge Nodes (i.e. GW and AP) and supports any kind of access technologies (such as Wi-Fi and GSM, L2 Switches). Thus, typical mobile-operator services such as roaming or hand-over can transparently be implemented on-top of WiBACK, which provides interfaces for capacity management and traffic classification.

A CLOSER LOOK AT WIBACK HARDWARE

The *WiBACK Controller* is the gateway (GW) to an external network and, hence, is usually located at the boundaries between a WiBACK backhaul network and a rather fixed infrastructure network. Most of the network logic is implemented in this node, including monitoring and network management functions. Conceptually, multiple Controllers can be operational in a a network, in order to reduce the risk associated with a single point of failure.

The Controller manages traffic paths inside the WiBACK network, and ensures that links with an associated service quality will never be overloaded. In particular, links for voice traffic will always run at very low latency and close-to-zero packet loss.

The *WiBACK Repeater* is a Backhaul Node with two radio interfaces. It is typically located outdoor and can be run on solar energy. While each repeater can bridge a distance of 22/50 km (tested/expected)[i], multiple repeaters can be concatenated to bridge much larger distances. Since each repeater only introduces a transmission delay of 1 to 2 ms, up to ten repeaters may be used to span distances of several hundred kilometers.

Figure 3: Ultra-Low-Power Two-Radio WiBACK Repeater

WiBACK repeaters can be clustered (via their Ethernet interface) to build a *wireless router*, an intersection inside a large wireless network. This allows the implementation of fully or partially meshed wide-area wireless networks, with redundant physical links.. The clustering concept allows the modem hardware to be located close to the antennas, thus keeping antenna cables short and reducing local interferences or cross-talk.

Following the heterogeneous WiBACK concept, repeater nodes can operate with different radio technologies. While IEEE 802.11 (WiFi) provides the cheapest chipsets, other technologies such as WiMAX are supported as well. The modular WiBACK concept makes it easy to support additional, even future radio technologies at low effort. A wireless repeater may use different, licensed and unlicensed, frequency bands on each interface. Spectrum management and coordination with external systems (ie.TV White Spaces Databases) is handled centrally by the WiBACK controller.

The *WiBACK Access Node* provides the interface to different access technologies such as Wi-Fi access points, GSM/UMTS/LTE base stations, Layer2 switches. Such devices can be connected via the Access Node's Ethernet interface which may operate in tagged (IEEE802.1q VLAN) or untagged mode.

WIBACK SOFTWARE

While the hardware consists of selected and energy-efficient commercial off-the-shelf components, the software defines the heart of WiBACK. **Error! Reference source not found.** depicts key functional building blocks which are:

- an SDN/MPLS-based traffic forwarding mechanism supporting transparent Layer2 bridging including IEEE8021.q VLAN trunking;
- an IEEE 802.21-inspired technology-independent network management;

- automatic radio-planning and topology management to set-up and maintain the underlying infrastructure (SON);
- automatic link calibration incl. MAC Layer Optimization for low-latency P2P-Operation;
- capacity management to assign available wireless resources and enforce access policies;
- extensive monitoring to detect performance issues and to support Traffic Engineering

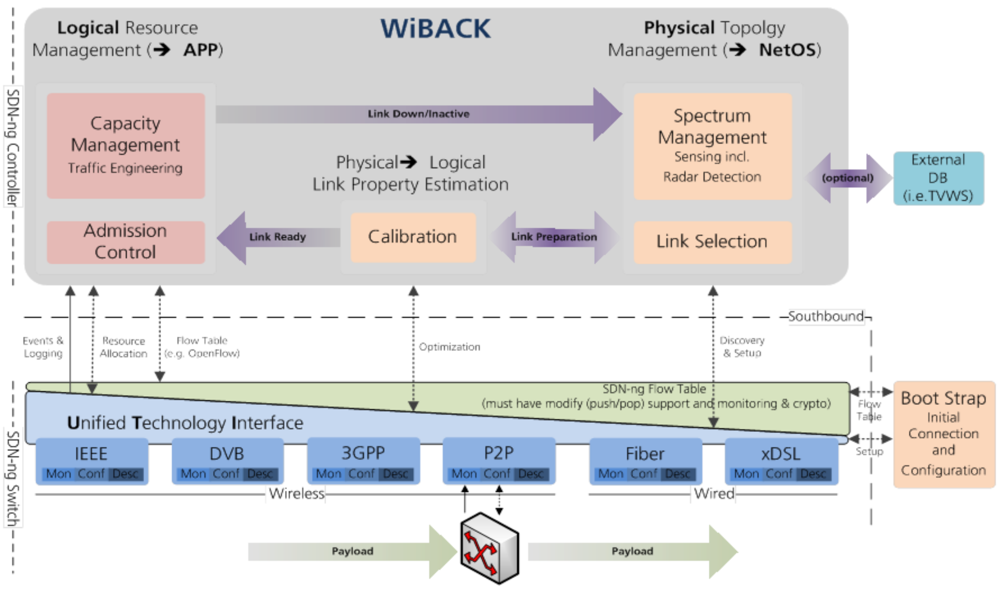

Figure 4- Key WiBACK Building Blocks and their relationship

Traffic Forwarding

SDN/MPLS-based traffic forwarding, as it is also used in traditional telecom operator networks, provides virtual tunnels to separate traffic of different traffic classes. Each data packet is associated with an MPLS label, which in turn is associated with a specific traffic class. Even when forwarded between the same radio nodes on the same radio links, a voice packet will experience a different handling than a data packet, and typically be forwarded first. Sophisticated traffic-engineering concepts ensure high network performance, efficient usage of available resources, and provisioning of guaranteed quality of service at the same time.

The use of MPLS also results in reduced demand on the hardware in terms of computing power, thus lower CAPEX and faster message forwarding. Transparent Layer2 forwarding, incl. support for IEEE802.1q VLAN trunking, ensures compatibility with higher-layer protocol such as IPv4 and IPv6. To that end, segments of a WIBACK network form QoS-aware link-local broadcast domains.

Network Control

IEEE 802.21, an international standard originally developed for inter-technology handovers, was extended by Fraunhofer to support an extended set of control functions. This extension is used to manage the MPLS paths across the network, and to collect and provide network monitoring information. Its technology-independent nature allows WiBACK to integrate any type of radio network technology, provided that an appropriate control interface has been made available. A central component, the *Interface Management Function (IMF)* provides a uniform and technology agnostic interface to higher layers. MAC adapters located logically below the IMF are responsible for mapping a set of generic primitives onto technology specific features and mechanisms. The higher layer modules on top of the IMF provide functionalities of traditional routing protocols and beyond, such as topology discovery, radio planning, channel assignment, route computation, or monitoring.

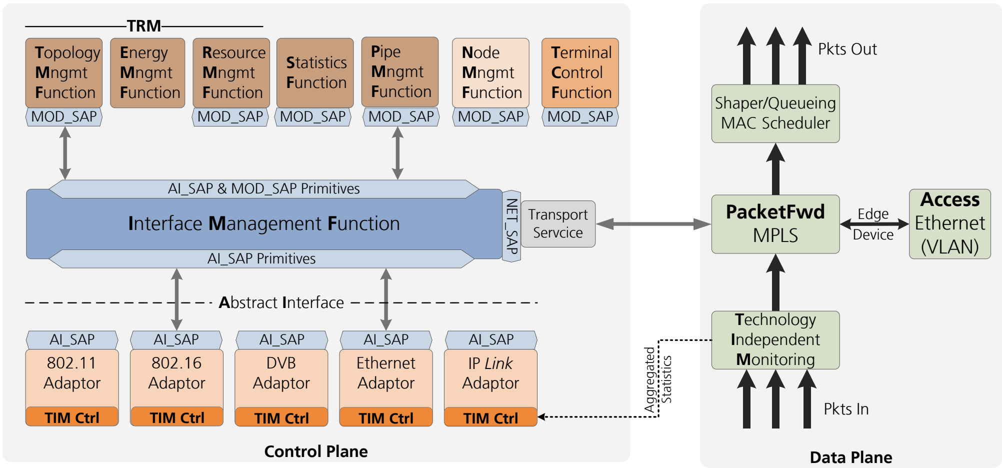

Figure 5 – The modular WiBACK Control Plane is complemented by an MPLS-based Data Plane

The control plane is based on a centralized management approach, where so-called *Master nodes* manage a set of *Slave nodes* in their administrative area. Dedicated management entities maintain the resource allocation and forwarding state of their network areas. Multiple Master nodes might be operational within each administrative area in a primary/backup configuration. Contrary to the rather distributed routing protocols such as Open Shortest Path First (OSPF) or Optimized Link State Routing (OLSR), the centralized approach offers the opportunity to perform network wide optimizations when allocating radio resources or when assigning the overall network capacity to best match payload demands.

Topology Management

Automatic topology management, provided by the *Topology Management Function (TMF)* automatically discovers neighboring nodes, sets up control paths between each node and a Master node, reacts on new nodes as well as node failures, and provides mechanisms for fast re-routing if necessary. The WiBACK Controller uses TMF information to assign radio channels (frequencies) or to select optimal end-to-end paths based on selectable criteria or policies. Monitoring information such as signal quality, link errors or end-to-end QoS violations determine may trigger actions of the self-healing process.

TMF implements a ring-based approach where a Master node first brings up its own radio interfaces and determines the optimal radio configuration. This is computed based on the capabilities of the radio interfaces and the ambient spectrum usage assessed by passive channel utilization analysis. Additionally, TMF may coordinate with external spectrum allocation databases (i.e. TVWS). Once this process is complete, the Master starts sending WiBACK beacons to all its active interfaces to inform adjacent Slave nodes about its availability.

Slave nodes determine their configuration during the bootstrap phase and then switch into a passive beacon scan mode in which they periodically scan all administratively permitted channels for WiBACK beacons sent by a Master node or already associated Slave nodes. Once they detect WiBACK beacons they will attempt to associate with the sending node. If multiple WiBACK beacons have been detected, they will be sorted and associations will be attempted starting with the highest rated sender.

Link Calibration

An automated Link Calibration is performed for each newly activated link with the goal to determine, for example, the proper range, modulation and coding (MCS) as well as TxPower settings for each link. Based on this information, the resulting logical link properties, such as capacity and latency are estimated. Those properties serve as the basis of the RMF's constraint-based path computation. In the WiBACK cross-layer design, the TMF may specify the maximum TxPower allowed on a given link, while the respective technology is free to optimally adjust itself to the present channel conditions within the limits set forth by the TMF (i.e. TxPower, MCS, MAC timings).

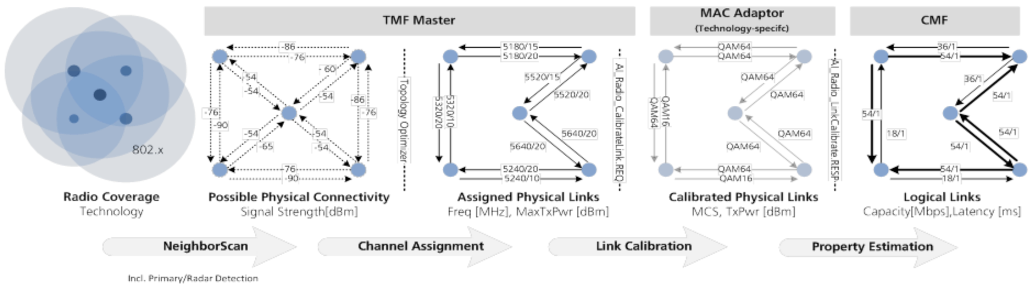

Figure 6 - The Link Calibration procedure play a crucial rule since it performs physical link optimization and maps the physical link configuration onto a set of logical link properties required for resource management and Traffic Engineering (TE).

Resource Management

Logical Resource (i.e. capacity) management is provided by the *Resource Management Function (RMF)* to ensure that the capacity of a link is never exceeded. Based on configurable policies RMF may adjust its resource allocations to best match end-user demands. Upon association of a new Slave, the TMF re-computes the optimal channel configuration for all available physical radio links in the WiBACK network and may trigger network reorganizations with the goal to optimize the overall network performance (i.e. capacity or latency).

Multi-Layer Technology Independent Monitoring (TIM)

WiBACK maintains extensive network monitoring statistics of its nodes, links and MPLS LSPs, so-called *Pipes*. This information is continuously examined by the self-management modules to detect possible network problems such as link errors or end-to-end QoS violations. Statistics on the monitoring data are maintained by the *Statistics Functions (SF)*. A Web Interface provides access to this information for administrators. Passive monitoring is used where possible to keep the load caused by monitoring/probing frames at a minimum.

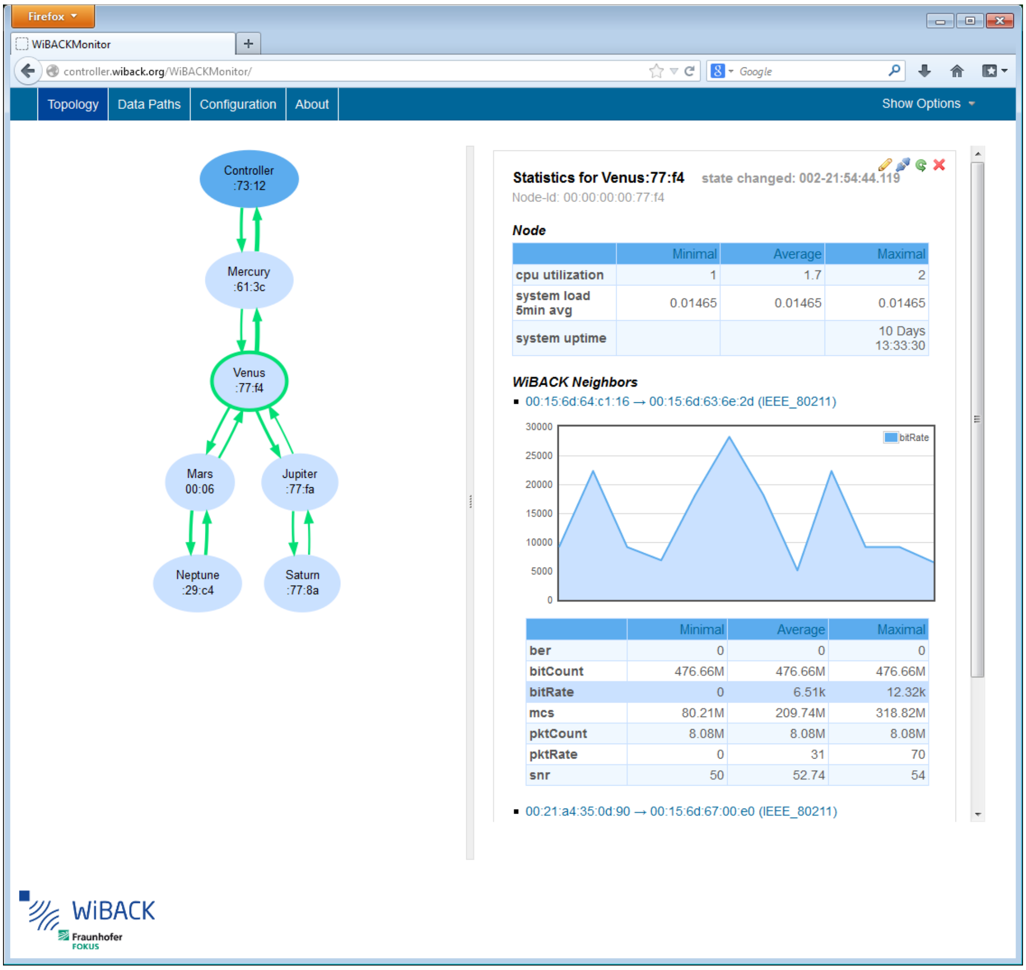

Figure 7 - Live Monitoring Data may be accessed via a Web Interface

STATUS AND OUTLOOK

WiBACK has been developed by Fraunhofer FOKUS. Initial research and development was funded internally (by Fraunhofer) as well as by grants from the European Commission and the German Ministry of Research (BMBF).

While R&D is continuing to add and improve functionality such as energy awareness, self-healing, multicast/broadcast capabilities, and security, stable snapshots with increasing functionality are continuously being tested “in the field”. Two pilots in Germany have been set up to connect rural areas while pilots in Africa are being set up to establish connectivity in emerging and previously unconnected regions. The pilots allow us to evaluate reliability, vulnerability in outdoor conditions, operational costs, and customer satisfaction.

The local utility company in Bruneck, Italy (Statdwerke Bruneck) has chosen WiBACK to extend the reach of its city-wide fiber-network to service remote locations without access to the fiber network.

MORE INFORMATION

For further details, please visit our website at http://wiback.org.

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[i] Subject to regulatory EIRP limits