Appropriate wireless technologies for extending 3G coverage to isolated rural communities

SEVENTH FRAMEWORK PROGRAMME

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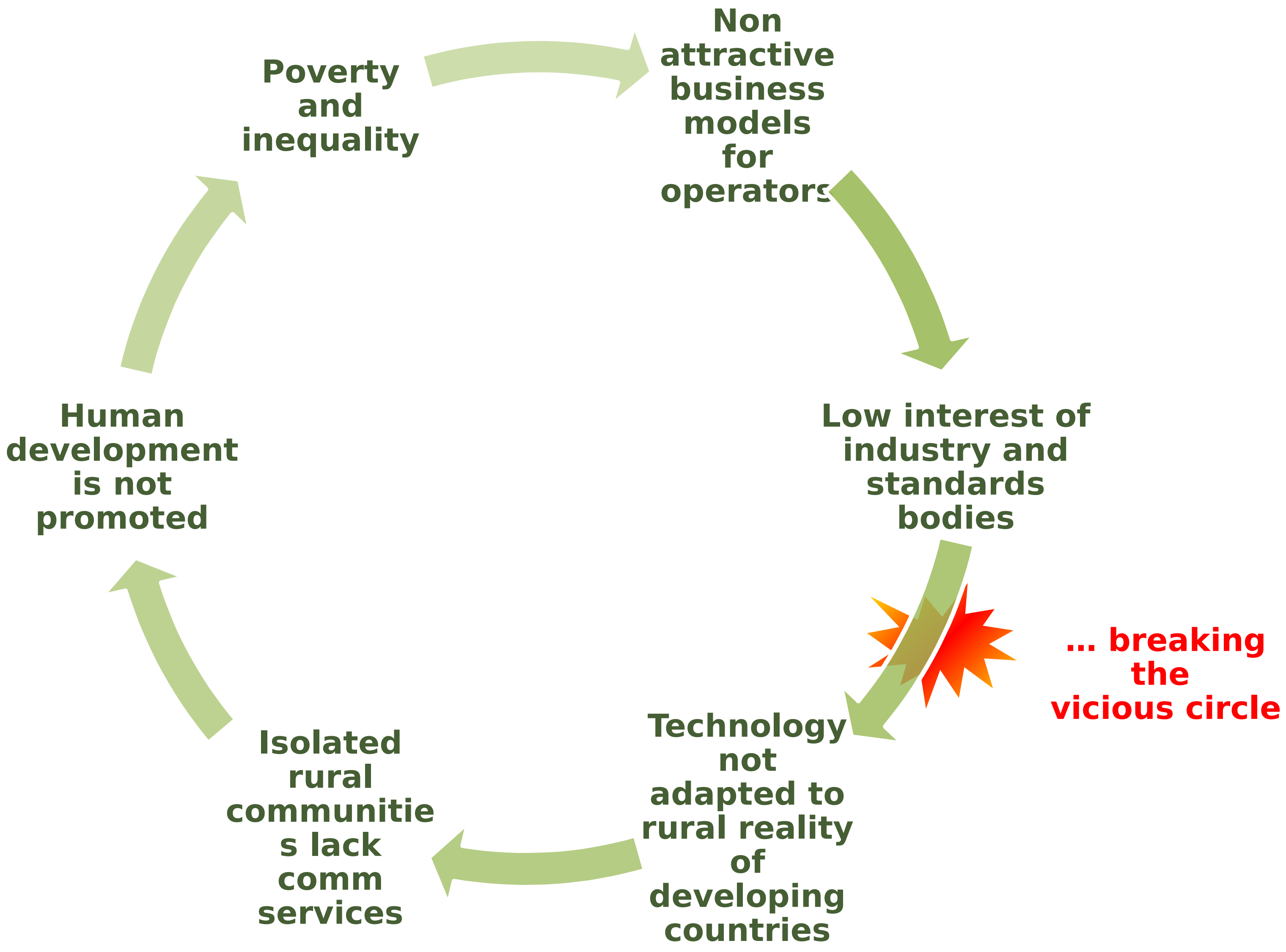
Context analysis

Remote rural areas arise little interest to operators due to:

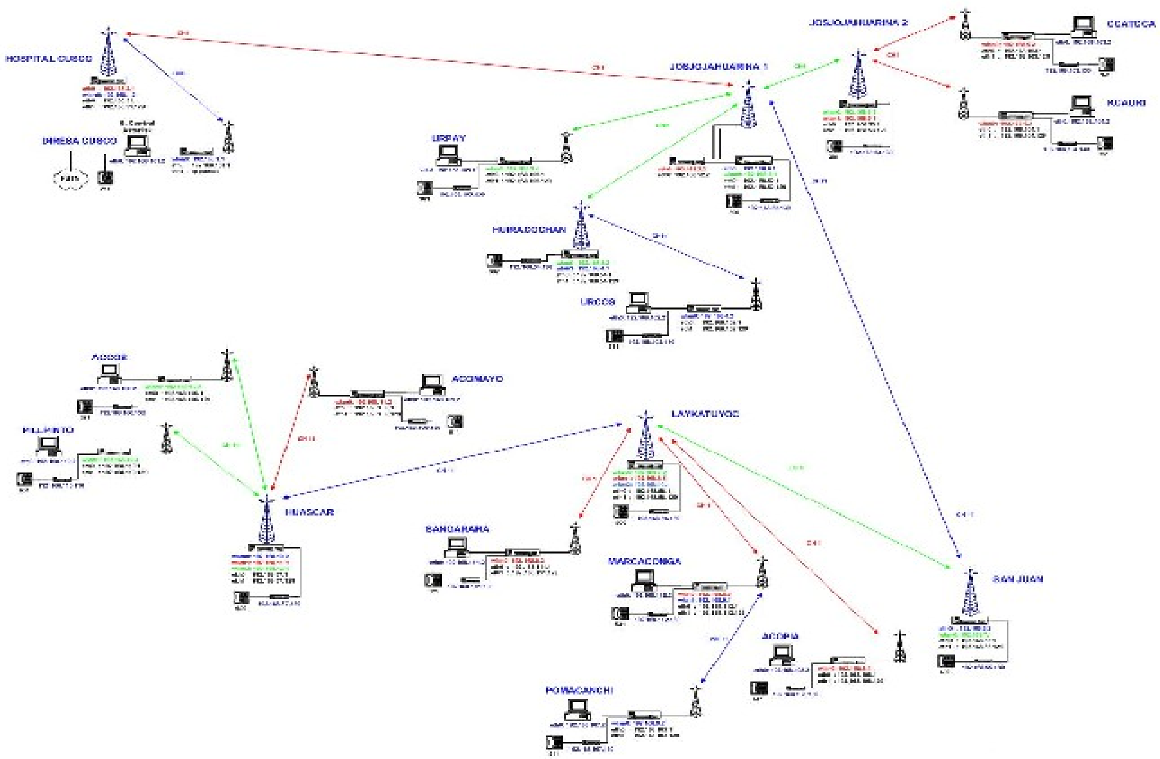
- Low density of customers
- Difficulty of access
- High deployment costs
- Absence of electricity grids
- Low incomes of subscribers

which has traditionally resulted in low return-on-investiment or non-viable business models.

Context analysis



Previous work...



- First WiID network for telemedicine: CuzcoSur (2005)
- Health facilities in several villages connected to the Cuzco Hospital (Peru)
- After 2006, the Spanish NGO ONGAWA extended the network and now in is bigger, redundant and covers other services.
- Later: other WiLD networks in the Amazon forest...

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Current project: TUCAN3G

- Cofunded by EC (FP7) and the Peruvian government
- **Objective**: Obtain a technologically feasible and yet economically sustainable solution for the progressive introduction of voice and broadband data services in rural communities of developing countries, using commercial cellular terminals, 3G femtocells (and its possible evolution to 4G) and heterogeneous backhauling (WiLD-WiMAX-VSAT)
- Work Packages:
  1. Finding a suitable business model
  2. Enhancing the access network using femtocells
  3. Enhancing the transport network using WiFi-WiMAX-VSAT backhauling
  4. Checking the viability through demonstration platform

http://www.ict-tucan3g.eu/

Current project: TUCAN3G

Education/Research Institutes

Governmental Agency

Manufacturer

Network operators

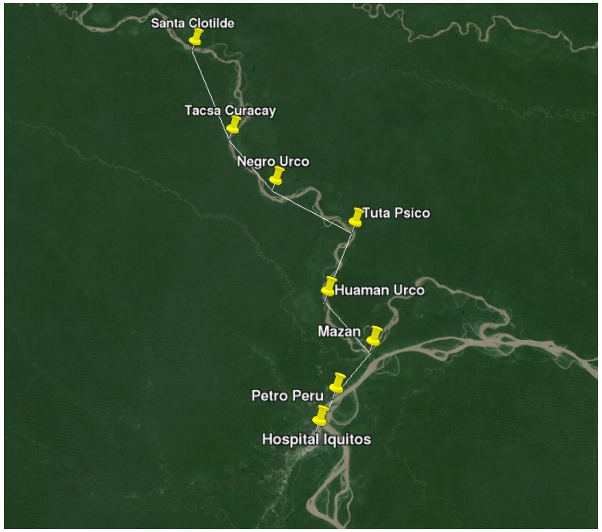
Technology providers

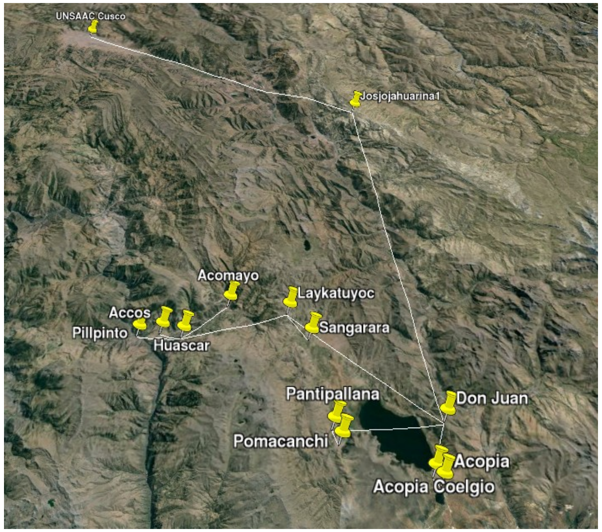
Technology exploitation consultants

The telecommunications infrastructure required to bring connectivity to 3G users requires three network segments:

* **Core network**: high performance systems interconnected with high capacity links.
* **Access network**: user terminals and the base stations to which these users connect.
* **Transport network (Backhaul)**: complementary infraestructure that connects the access network to the core network

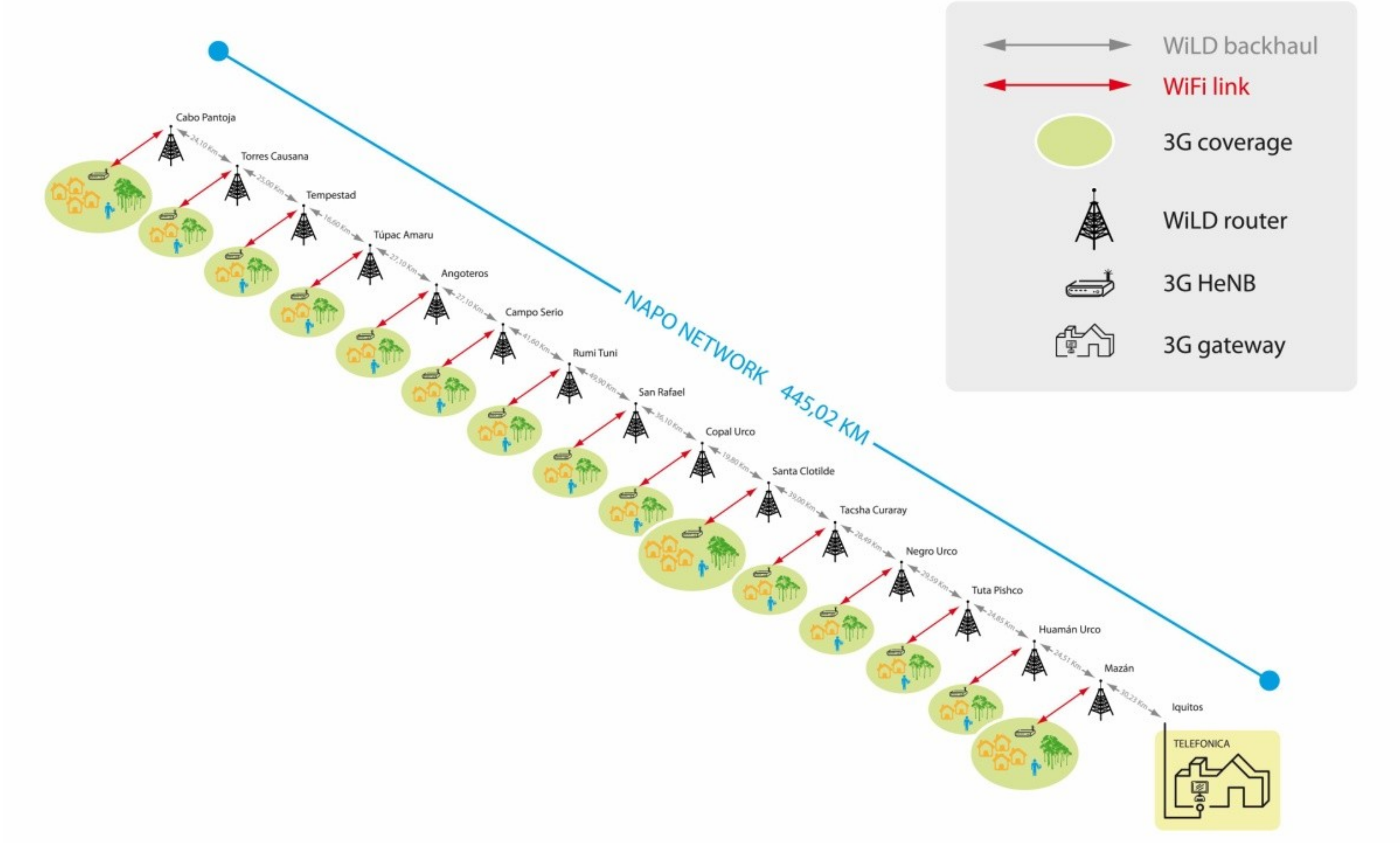
The backhaul usually consists of a single high-capacity low-latency communication link, but this is not a valid solution for TUCAN3G and common technologies aren't appropriate.





Scenario for the demo platform: the Napo network

- **The Napo network: a WiLD network for telemedicine deployed in the Amazon forest since 2007**



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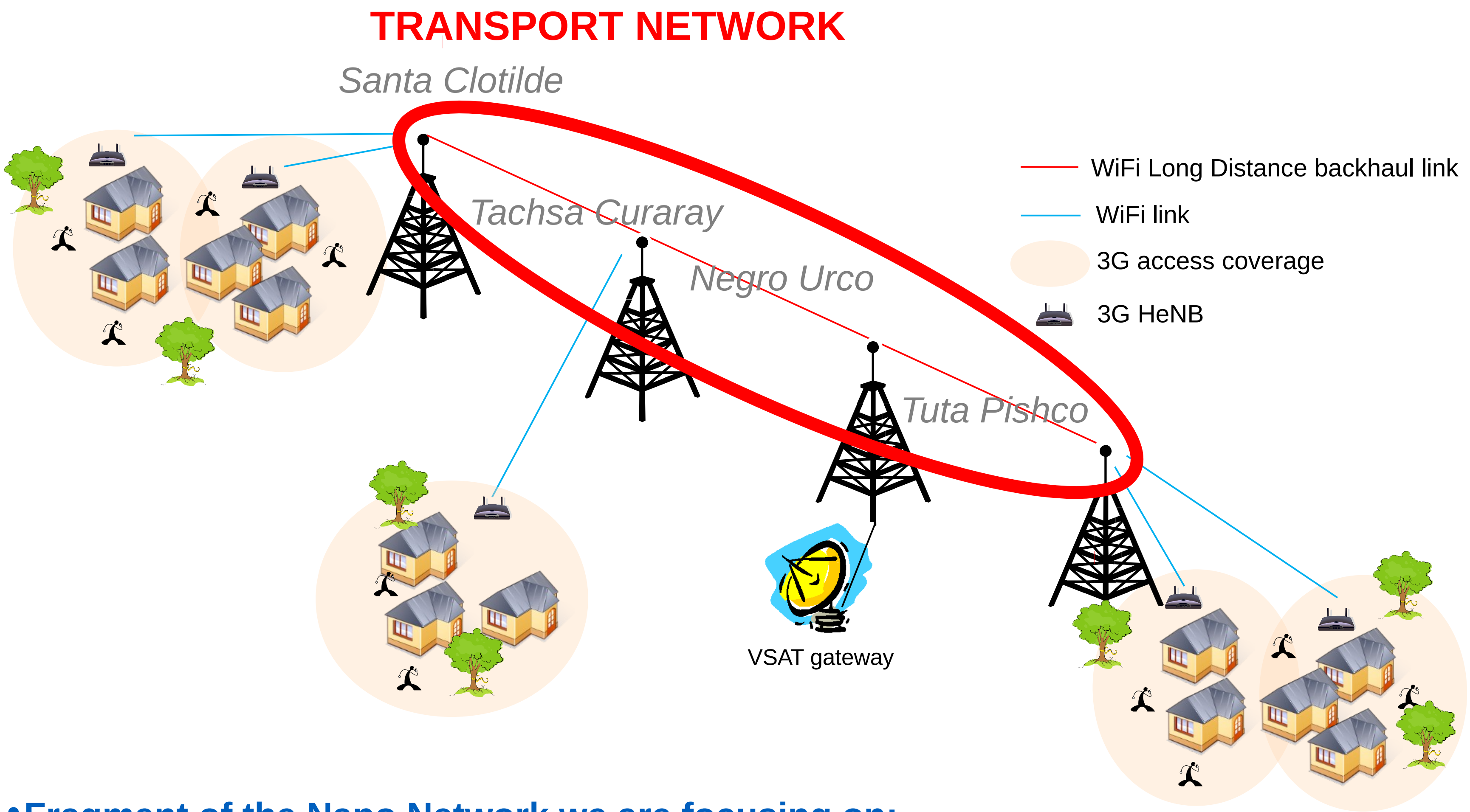


- **Fragment of the Napo Network we are focusing on:**
  - **We use the towers of the Napo network in four villages**
  - **We install 3G femtocells in this villages**
  - **We deploy a parallel transport network in this segment**

Rural **backhaul solutions** for remote areas:

- Need to cover long distances
- To connect small amounts of users

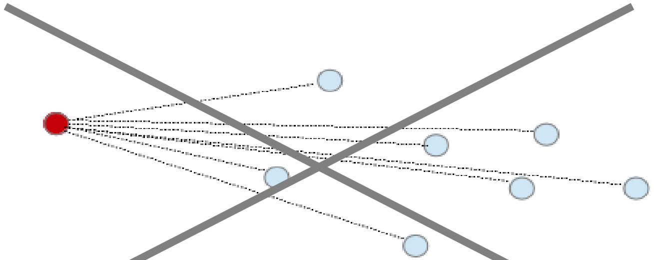
Which makes advisable the use of

- Low-cost technologies that may still meet QoS requirements
- Shared Multihop networks for several base stations, instead of separate direct links
- Optimized solutions that get the best performance at the lowest cost

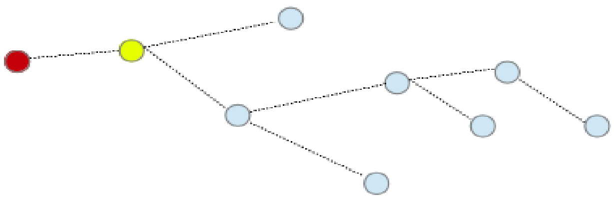
Technologies we consider for the backhaul:

- **WiLD** (WiFi for Long Distances), either stardard 802.11n or proprietary solutions with alternate TDMA MAC.
- **WiMAX** (802.16 WirelessHUMAN)
- **VSAT** links

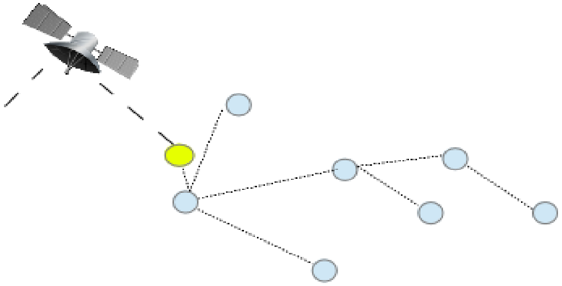
Non-licensed bands are considered due to the lack of interferences in isolated regions.



a) Backhaul link to each small cell in the rural area from an edge node in the operator's network.



b) Terrestrial multi-hop network for backhaul. Closer locations are linked to an edge node in the operator's network, possibly through one or more relays. Further locations use other nodes in the network as relays.

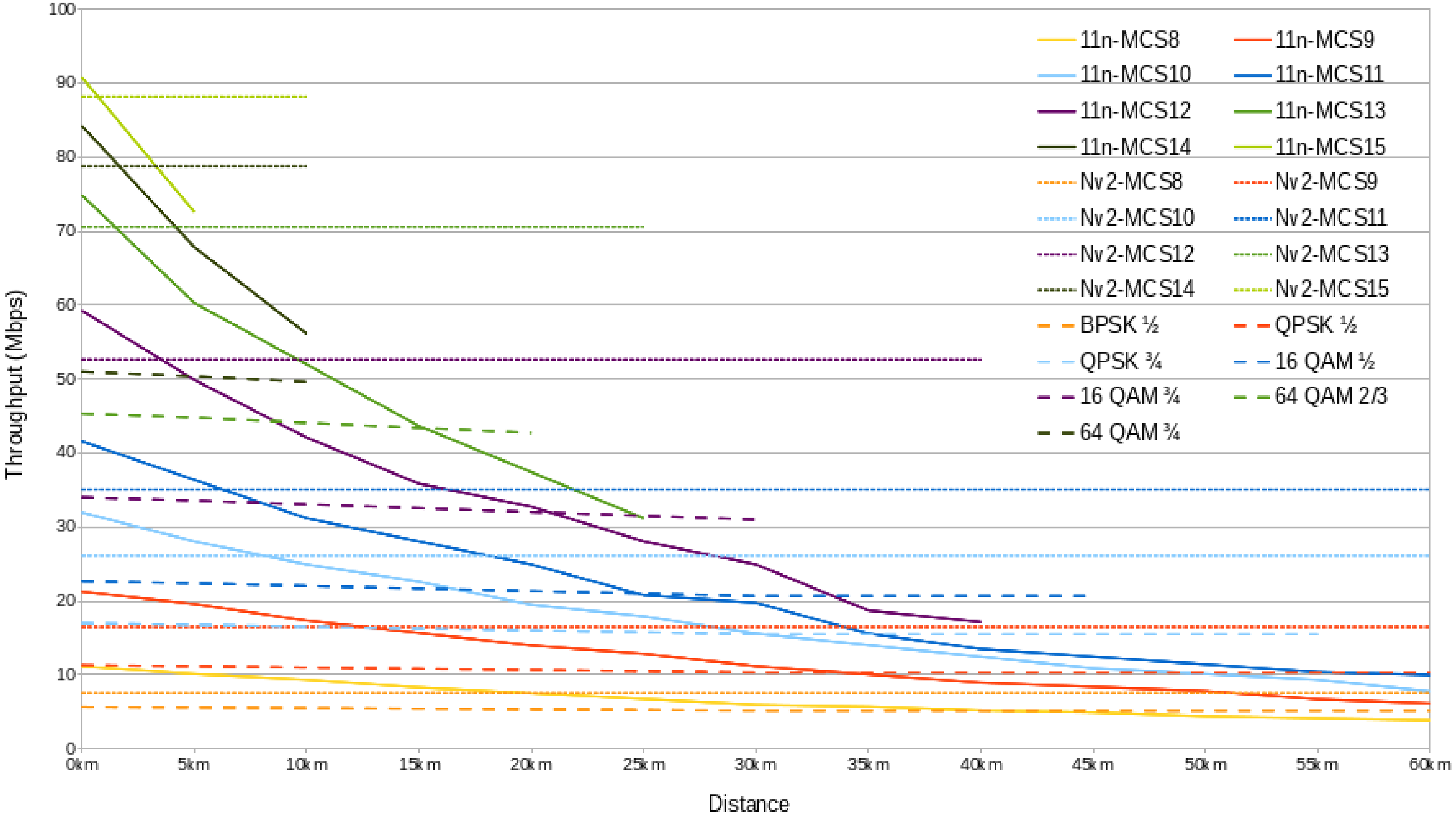


c) Like (b) but a VSAT gateway is used because the distance from the closest location to the edge node in the operator's network is too long to consider terrestrial multi-hop connection, even through relays.

In order to assess the appropriateness of each of these technologies, we must:

Characterize the traffic that needs to be transported	Determine the QoS that needs to be offered.
Voice (telephony)	Low delay: < 150 ms end to end Stable throughput ~ 80 kbps/channel Low packet-loss: < 2%
Signalling traffic exchanged between HNBs and their controller	Medium delay (systems are very tolerant, up to seconds) Low throughput, bursty, < 1% of total traffic Low packet-loss: << 1%
Data traffic in general	Variable delay requirements, considered BE Bursty traffic, tends to be expansive Packet-loss helps to auto-adjust

Comparison of WiLD and WiMAX for delay bounded to 5 ms



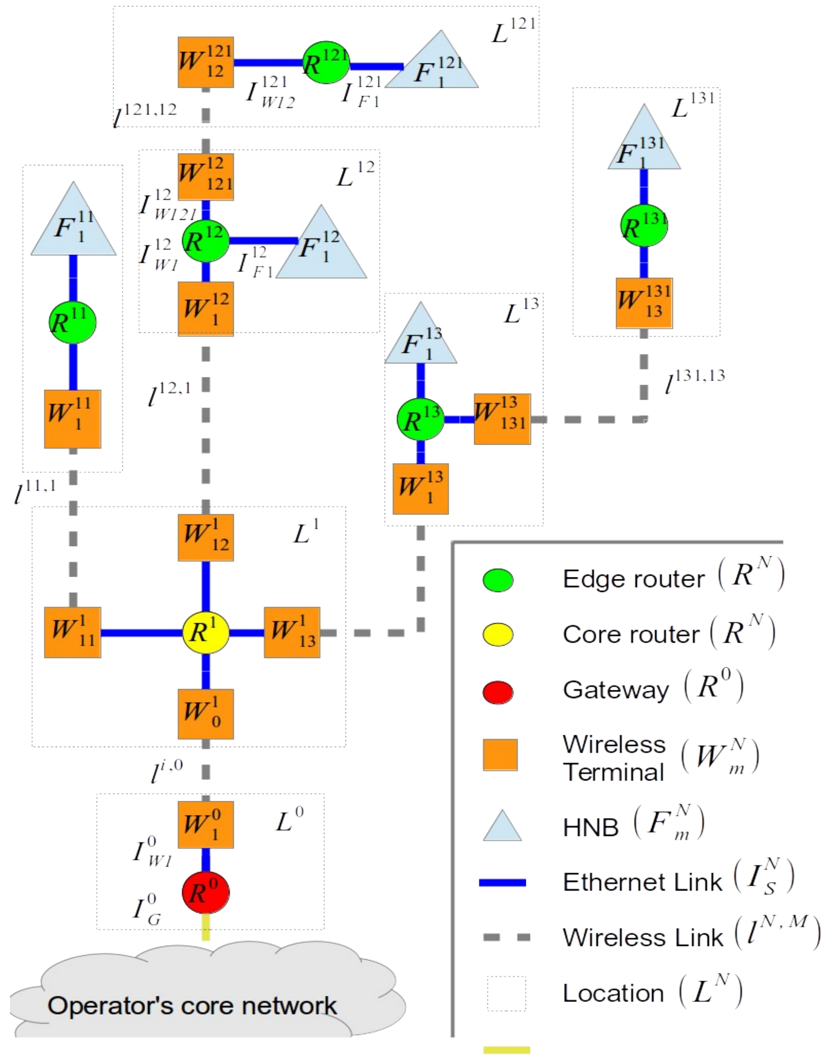
Check: ¿may a real rural network be deployed with the capacities supported by the proposed technologies?

Example for Napo Network: capacities with per-hop delay under 5 ms

Link	Distance	Thr. required (Kbps)	WiMAX (Kbps)	WiFi (Kbps)	NV2 (Kbps)			
Santa Clotilde - TC	39.1 Km	6412.8	16QAM1/2	20672.9	MCS12	17160	MCS12	52656.4
TC – Negro Urco	25.5 Km	9248	16QAM3/4	31009.4	MCS13	31200	MCS13	70598.6
Negro Urco – Tuta Pisco	32.2 Km	12083.2	16QAM3/4	31010.4	MCS12	24960	MCS12	52656.4
Tuta Pisco - HU	26.5 Km	14918.4	16QAM3/4	31527.7	MCS13	31200	MCS13	70598.6
HU – Mazan	22.3 Km	17753.6	16QAM3/4	31527.7	MCS13	31200	MCS13	70598.6
Mazan - Petro	19.9 Km	24486.4	64QAM2/3	42728	MCS13	37440	MCS13	70598.6
Petro – Hospital Iquitos	11.7 Km	24486.4	64QAM2/3	43419	MCS13	43680	MCS13	70598.6

- WiLD and WiMAX seem to be useful for the backhaul.
- Condition: traffic is shaped before entering each link in order to keep it working under saturation.
- If the previous condition is not met
  - The per-hop delay may be >> 5 ms
  - The packet-loss may be high
  - Queues in wireless systems cannot be controlled

  - We must control the traffic in every hop for
    - Traffic differentiation
    - Traffic shaping
    - QoS monitoring



End-to-end delay in every path is limited and imposes a limit to the sum of per-hop delays

$$D^{k}_{Fi} \geq D^{k} + D^{k,j}_{l} + D^{j} + D^{j,i}_{l} + \ldots + D^{a,0}_{l} + D^{0}$$

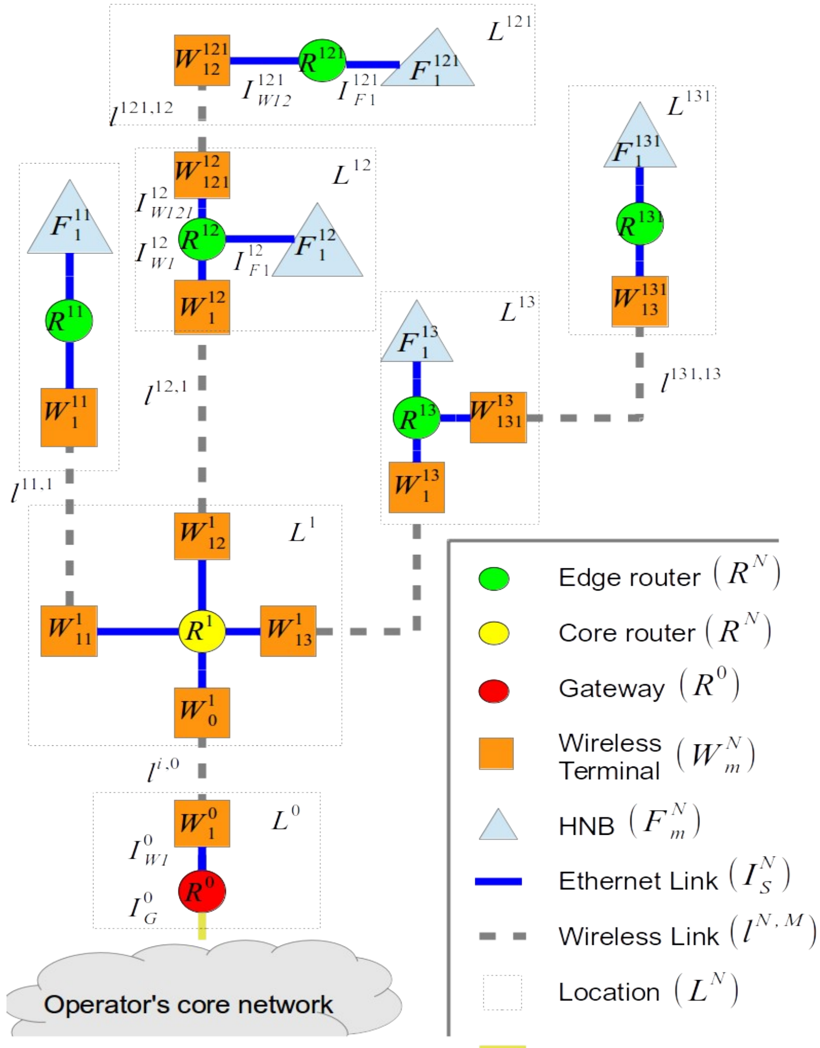
The maximum throughput expected from each HNB determines the expected throughput in subsequent links

$$S^{k,j} = \sum_{\forall x} S^{x,k} + \sum_{\forall y} S_{y^{k}}$$

The capacity of each link in the load point that limits the delay to $D_l^{k,j}$ must meet the following conditions for arbitrarily low probabilities:

$$P\left\{C^{k,j}_{R}(t) \geq S^{k,j}\right\} \geq \chi_{c}$$

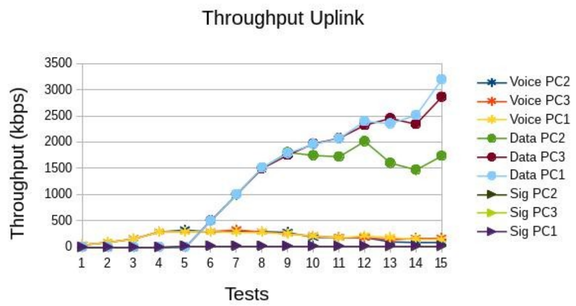
$$P\left\{D^{k,j}_{R}(t) \geq D^{k,j}_{l}\right\} \geq \chi_{d}$$

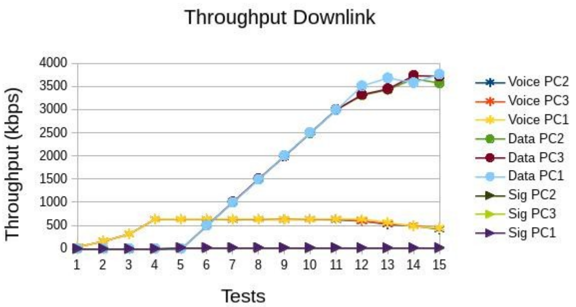


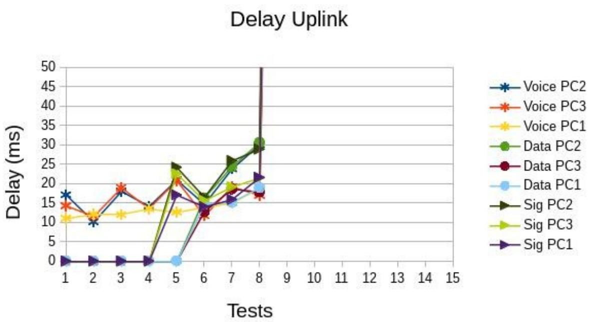
Two approaches are compared for coordinating the traffic control in all nodes of the BH in order to perform the objectives of traffic differentiation and traffic shaping consistently in all nodes?

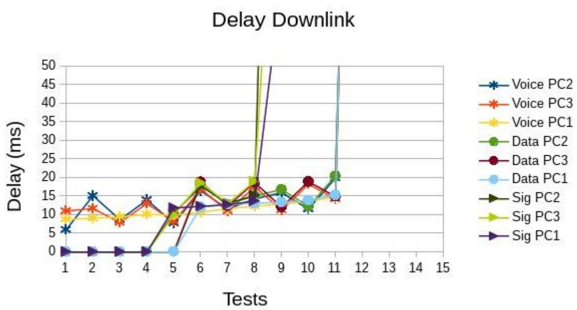
	Advantages	Drawbacks
DSCP	Supported by all the hardware systems, easy to deploy and scalable.	Priorities, no real QoS
MPLS	A robust bandwidth reservation is provided for each connection.	Less efficient in terms of statistical multiplexing

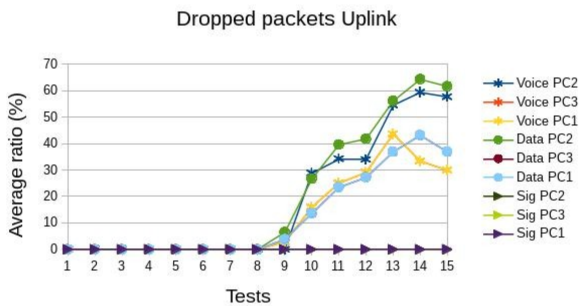
Experimental testbeds with neither traffic shaping nor priorities

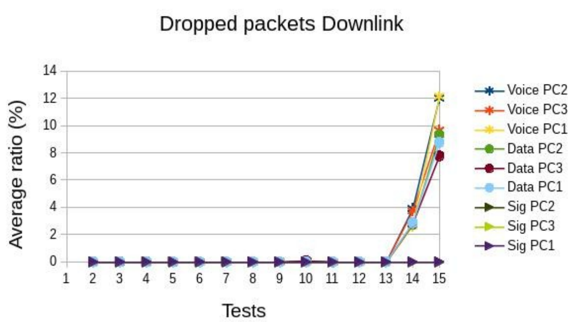




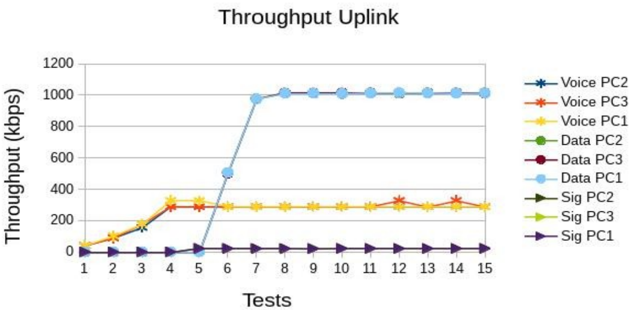


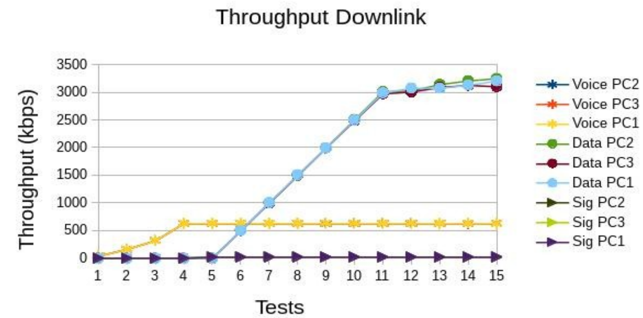


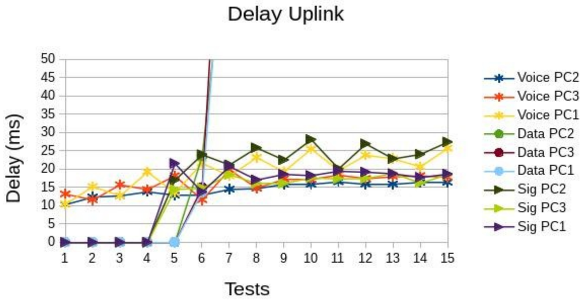


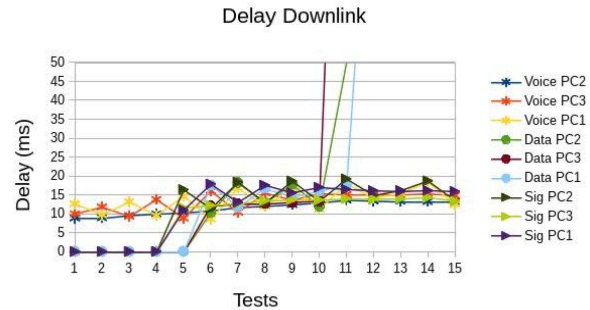


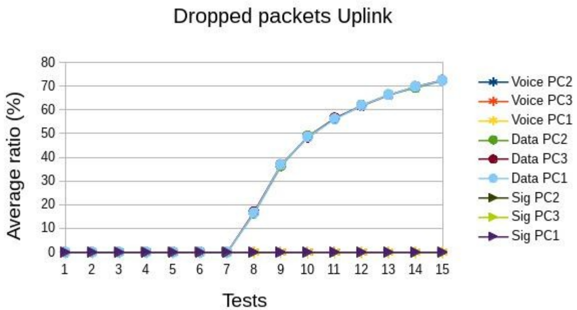
Experimental testbeds: results with HTB in edge nodes, NV2 and WiMAX

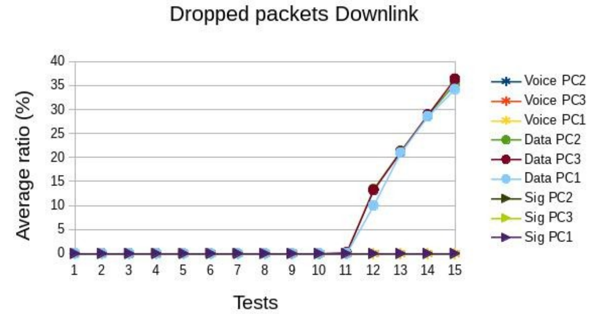






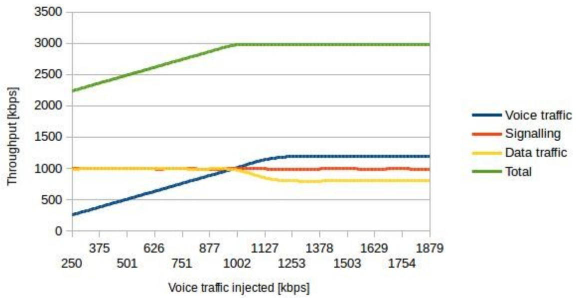


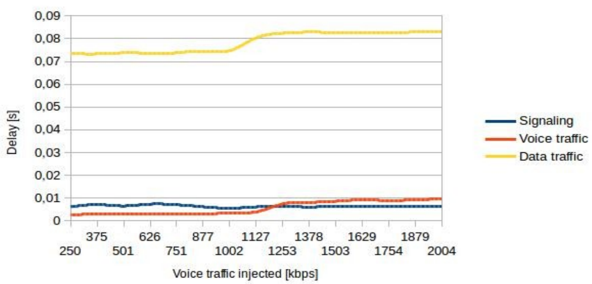


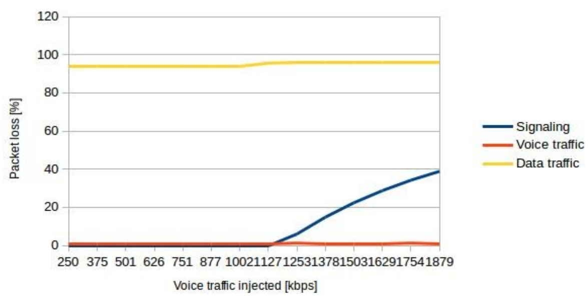


Experimental testbeds:

With MPLS (traffic prioritized with a queuing discipline before entering MPLS)







- Inter-tunnel protection is excellent

- Low-cost implementations do not seem to permit
  - traffic aggregation in intermediate switches
  - traffic prioritization in intermediate switches

- QoS behaviour is good as far as end-to-end tunnels are a valid solution

- From a theoretical point of view MPLS does not offer substantial advantages

- Seen potentially interesting for isolating a virtual BH from the rest of the traffic in a common infrastructure.

Conclusions

- We are still in the process for the real testbeds in the Napo network and the Balsapuerto network in the Amazon forest, but
  - The proposed solutions seem to satisfy the operator's requirements for these scenarios
  - The only issue: many operators will not accept to work with non-licensed bands.
- Until here the solution is solid but not optimal. Now we are working in optimization of both the access and the backhaul networks

Questions ? Suggestions ?

Thank you !

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