

# A tiered mesh network testbed in rural Scotland

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*joint work with  
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# Rural broadband

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- Broadband in rural areas:
  - ▶ The “**everyone has the right to have a phone**” policy.
  - ▶ Distances far beyond DSL coverage.
  - ▶ **Low population density** make "Fibre to the Home/Curb/Building" techniques economically unfeasible.
  - ▶ Satellite (**VSAT**) expensive and unsuited for interactive applications
- We are building a testbed to enable research on **Low Cost Broadband Wireless Access (BWA)** in remote and rural areas.



# Related work

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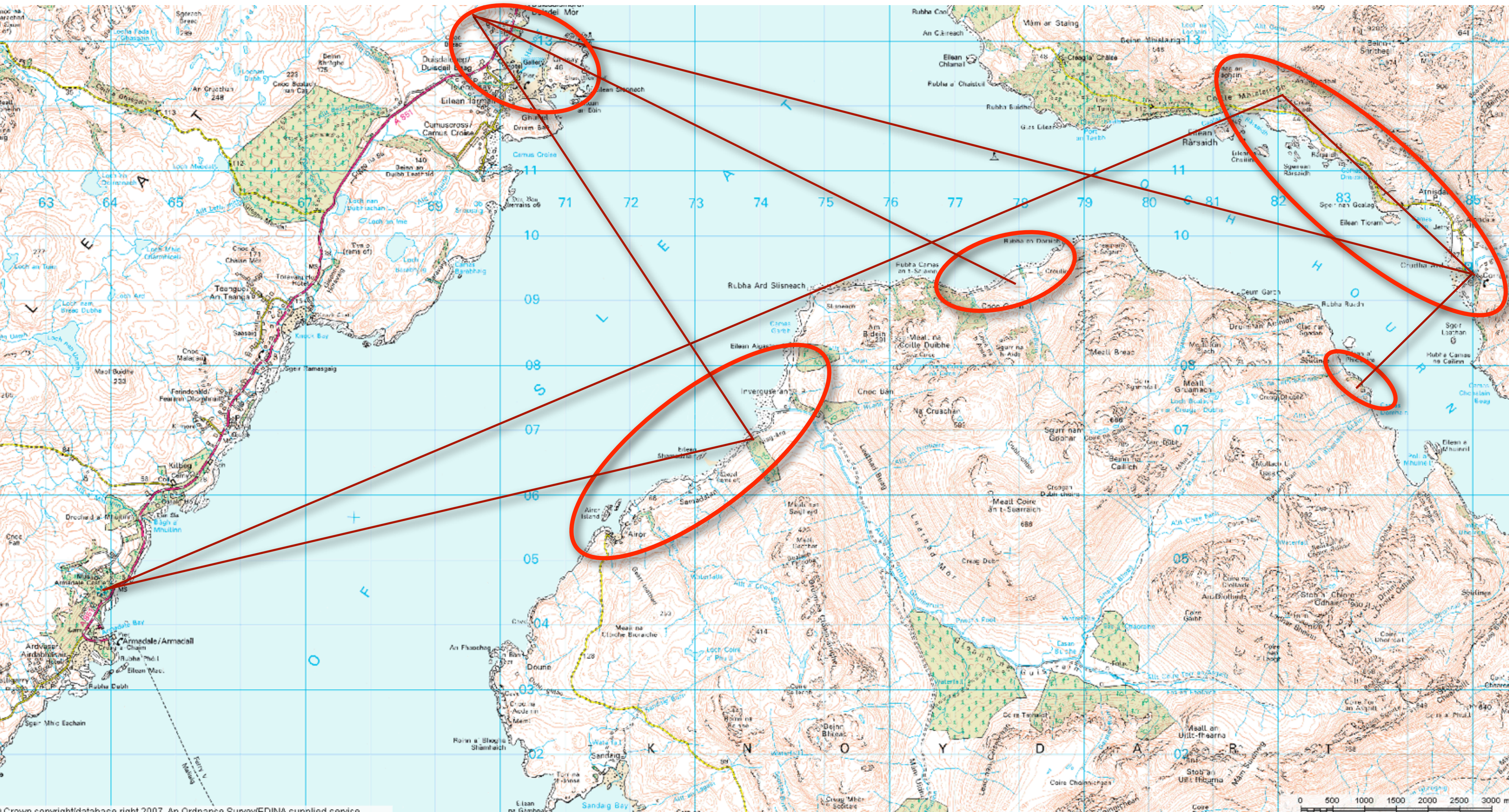
- **Outdoor urban mesh network** testbeds, such as:
  - ▶ MIT Roofnet
  - ▶ TFA Houston
- **Outdoor rural mesh networks** testbeds, such as:
  - **research** testbeds
    - ▶ DGP-India
    - ▶ TIER-Berkeley
    - ▶ QualRidge-UCDavis
  - **community** deployments
    - Wray village mesh

# Unique characteristics

- **Unique aspects of our testbed:**
  - ▶ long distance links **over sea**
  - ▶ **self-powered masts** with diverse power sources (wind and solar)
  - ▶ **weather conditions**
  - ▶ active **community** participation

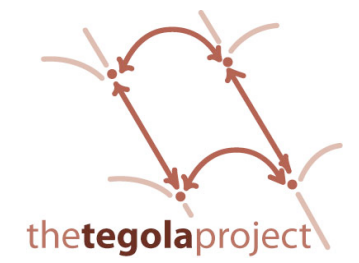


# The “tegola” testbed



# The art of building Masts

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# Modular approach (to get home dry...)

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- **Highlands weather,** transportation and limited daylight constrain operations
- Some installations are self-powered, other are not.
- Some installations offer “wireless local loops”, other are backbone-only.



# Modular approach

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- Most of the building materials are **recycled** (donated by locals).
- **Aluminum frame** that can be assembled in minutes.
- The masts are facing the sea: the setup must survive to high **wind loads**.





# Waterproofing

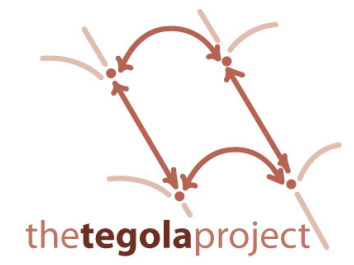
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- Silicone rubber and fiberglass to provide **additional waterproofing**.
- Sea salt and “upside-down rain” are interesting phenomena.



# Hardware

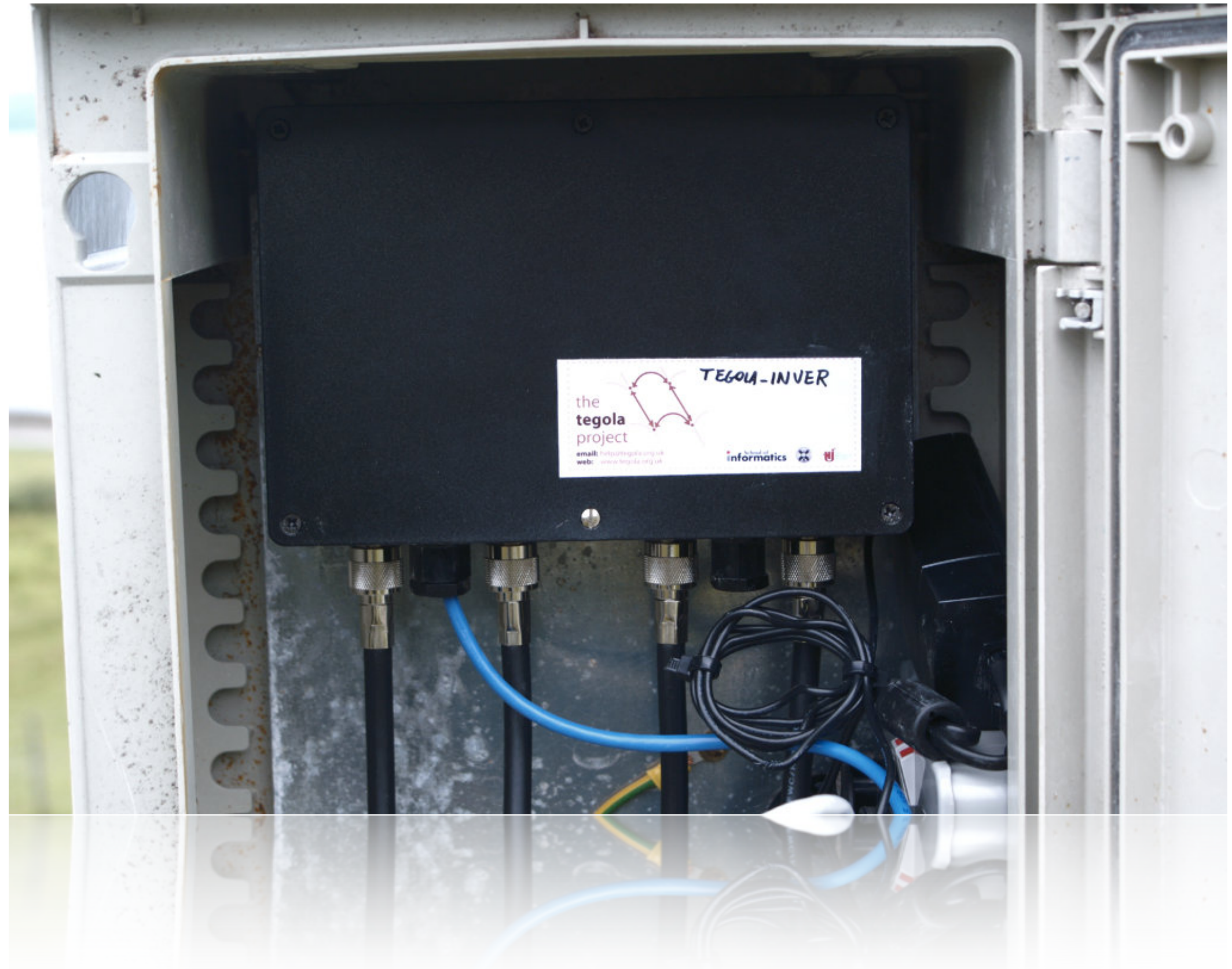
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# The backhaul platform

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- **Board:** Gateworks Avila GW2348-4
- **Equipped with:** Intel IXP425, 64MB RAM and 16MB Flash, 4x miniPCI slots, 2x Ethernet, 1x CompactFlash slot, temperature/voltage sensor.
- **Radio cards:** Ubiquiti Network XtremeRange5.



# Antennae

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- All the links are **dual-polarized** (Horizontal and Vertical).
- **29dBi dishes** from Pacific Wireless: HDDA5W-32-DP
- Chosen because:
  - ▶ Very rugged.
  - ▶ Very directional beamwidth ( $6^\circ$ ), negligible cross-polarization.
  - ▶ Radome to decrease the wind load by 30-40%



# Self-powered masts

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- Two of our installations “self-powered” by a combination of solar panels and wind generator.
- **Solar panel:**  
Kyocera KC130GH T-2:  
maximum 130W
- **Wind turbine:**  
Rutland Furlmatic 910  
90W@21mph, 24W@11mph
- **Battery:**  
Elecsol 125Ah 12V





The result

Mast at Isle Ornsay

# The CPE (Customer Premises Equipment)

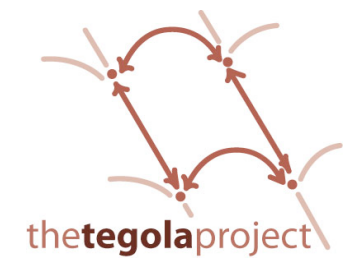
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- **Board:** PCEngines alix.3c2 with AMD Geode and 1GB of solid-state storage. 12V PoE.
- **Radios:** 2x 802.11abg hi-power miniPCI radios.



# Software and Routing

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# Software running on the nodes

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- **Linux 2.6**, based on the OpenWRT distribution.
- **MadWifi** as wireless driver.
- **Quagga** for routing.
- Custom-made software for data gathering and **statistics**.

# Routing

- **Ring topology** optimizes simultaneously redundancy and deployment cost.
- Each link is “**doubled**” by using two orthogonal polarizations.
- IP addressing scheme on private network:
  - ▶ **/30** nets for point-to-point
  - ▶ **/16** nets for local loops
  - ▶ The CPEs do **NAT** of the home network
- **OSPF** to redistribute the local subnets.
  - per-destination load-balancing.

```
t1.tegola.org.uk# sh ip route
Codes: K - kernel route, C - connected, S - static, I - ISIS, B - BGP, > - selected route, * - candidate for best route
K>* 0.0.0.0/0 via 194.35.194.1, eth0
0 10.0.0.0/24 [110/1] is directly connected, eth0
C>* 10.0.0.0/24 is directly connected, eth0
0>* 10.1.0.4/30 [110/12] via 10.0.0.2
0>* 10.1.0.8/30 [110/20] via 10.0.0.2
0>* 10.1.0.12/30 [110/29] via 10.0.0.2
0>* 10.1.0.16/30 [110/10] via 10.0.0.2
0>* 10.1.0.20/30 [110/29] via 10.0.0.2
0>* 10.1.0.24/30 [110/20] via 10.0.0.2
0>* 10.1.0.28/30 [110/22] via 10.0.0.2
0>* 10.1.0.32/30 [110/12] via 10.0.0.2
0>* 10.1.0.40/30 [110/11] via 10.0.0.2
0>* 10.2.0.0/16 [110/20] via 10.0.0.2
0>* 10.3.0.0/16 [110/30] via 10.0.0.2
0>* 10.4.0.0/16 [110/30] via 10.0.0.2
0>* 10.5.0.0/16 [110/21] via 10.0.0.3
C>* 127.0.0.0/8 is directly connected, lo
C>* 194.35.194.0/24 is directly connected, eth0
t1.tegola.org.uk#

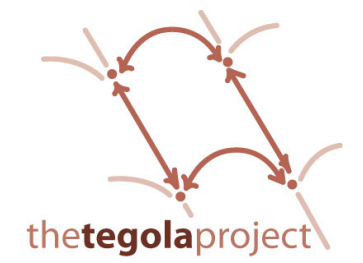
TEGOLA-Corran#
0>* 10.0.0.0/24 [110/20] via 10.1.0.9, ath1, 02:58:36
0>* 10.1.0.4/30 [110/19] via 10.1.0.9, ath1, 02:58:36
0 10.1.0.8/30 [110/10] is directly connected, ath1, 02:58:36
C>* 10.1.0.8/30 is directly connected, ath1
0 10.1.0.12/30 [110/9] is directly connected, ath2, 02:30:15
C>* 10.1.0.12/30 is directly connected, ath2
0>* 10.1.0.16/30 [110/21] via 10.1.0.9, ath1, 02:58:36
0 10.1.0.20/30 [110/11] is directly connected, ath3, 02:30:14
C>* 10.1.0.20/30 is directly connected, ath3
0>* 10.1.0.24/30 [110/20] via 10.1.0.13, ath2, 02:30:09
0>* 10.1.0.28/30 [110/18] via 10.1.0.13, ath2, 02:30:09
0>* 10.1.0.32/30 [110/27] via 10.1.0.13, ath2, 02:29:59
0>* 10.1.0.40/30 [110/29] via 10.1.0.13, ath2, 02:29:59
0>* 10.2.0.0/16 [110/20] via 10.1.0.9, ath1, 02:58:36
0 10.3.0.0/16 [110/10] is directly connected, ath0, 03:29:26
C>* 10.3.0.0/16 is directly connected, ath0
0 10.4.0.0/16 [110/10] is directly connected, eth0, 03:29:26
C>* 10.4.0.0/16 is directly connected, eth0
0>* 10.5.0.0/16 [110/28] via 10.1.0.13, ath2, 02:30:09
C>* 127.0.0.0/8 is directly connected, lo
TEGOLA-Beinn#

TEGOLA-Beinn# sh ip ospf neighbor

Neighbor ID      Pri   State           Dead Time   Address        Interface
10.0.0.2          1    Full/Backup     00:00:27   10.1.0.5       ath0:10.1.0.6
10.1.0.10         1    Full/DR         00:00:29   10.1.0.10      ath3:10.1.0.9
10.0.0.2          1    Full/Backup     00:00:29   10.1.0.17      ath2:10.1.0.18
TEGOLA-Beinn#
```

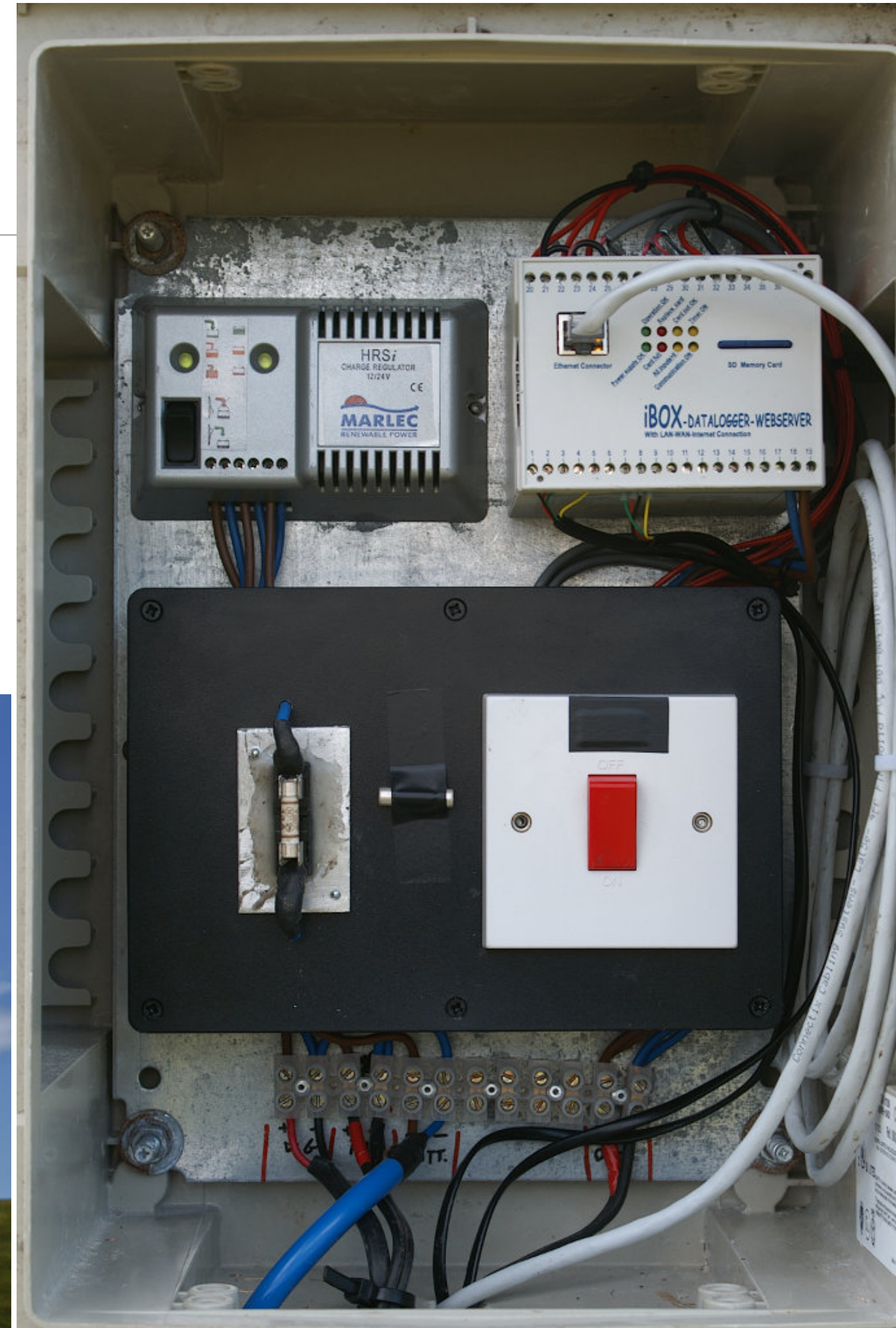
# Ongoing and Future Research

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# Direction #1: power studies

- Using solar and wind reduces the cost by a fourth but power sizing issue is still **unclear**:  
How does power consumption of the hardware vary?  
Are the “solar/wind” models and data realistic?
- We equipped one of our masts with an **IP-enabled datalogger** to allow data post-processing.



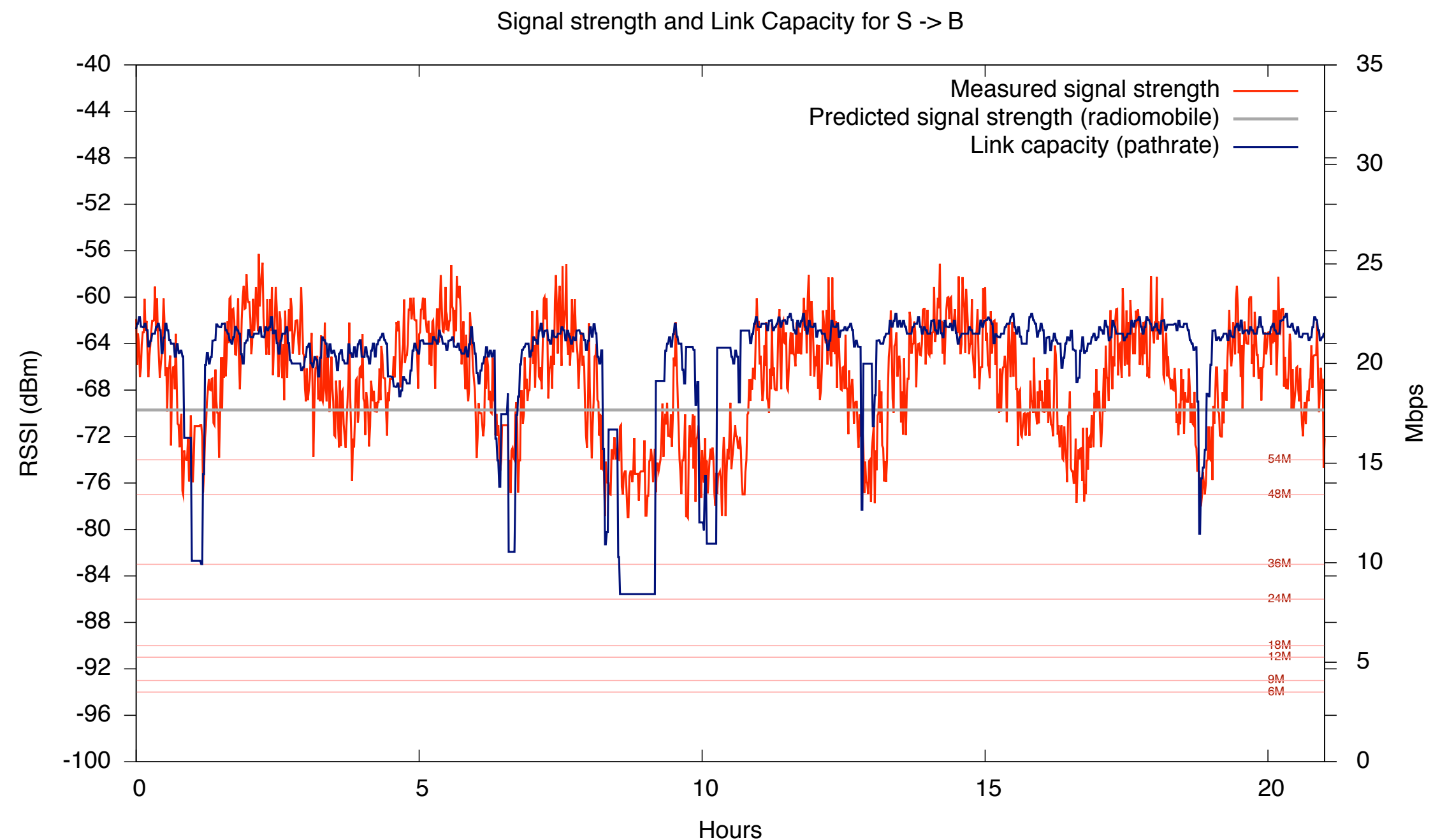
# Direction #1: power studies

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- In building a self-powered mast, the cost of the power subsystem is much higher than the electronics and the antennae.
- **Our board requires:**
  - ▶ 5-6W for the Gateworks Avila board
  - ▶ 4-5W for each of the miniPCI interfaces, if operated at “close to maximum” power levels.
- **Open questions:**
  - ▶ Is it possible to reduce these requirements without affecting the user?
  - ▶ What’s the cheapest way to provide an uninterruptible power source?

# Direction #2: propagation over sea water

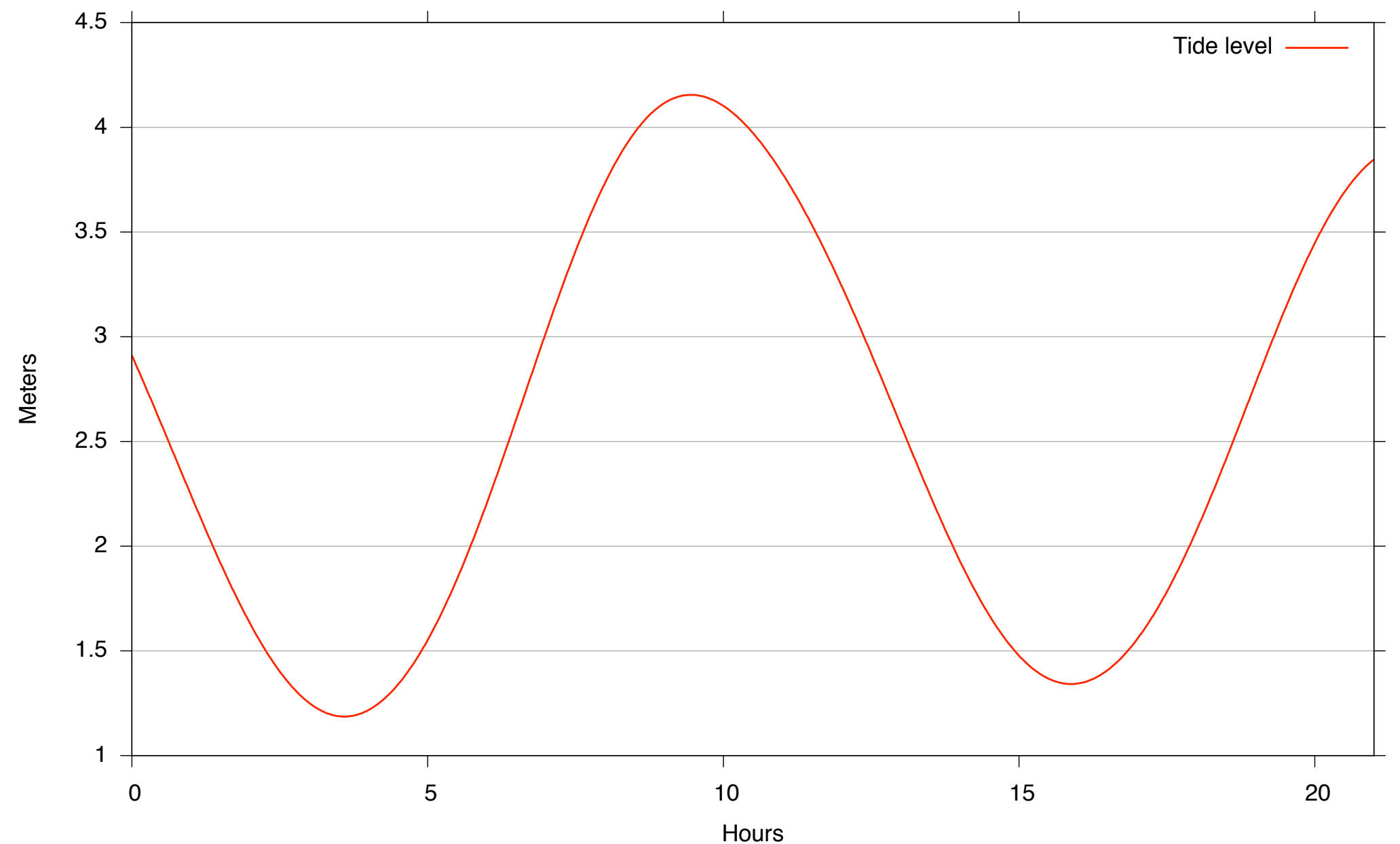
- Most of our links travel **over the sea** for long distances (max: 19km) at low altitudes (40-100m)
- Noticed **severe periodic fluctuations** in the signal strength.



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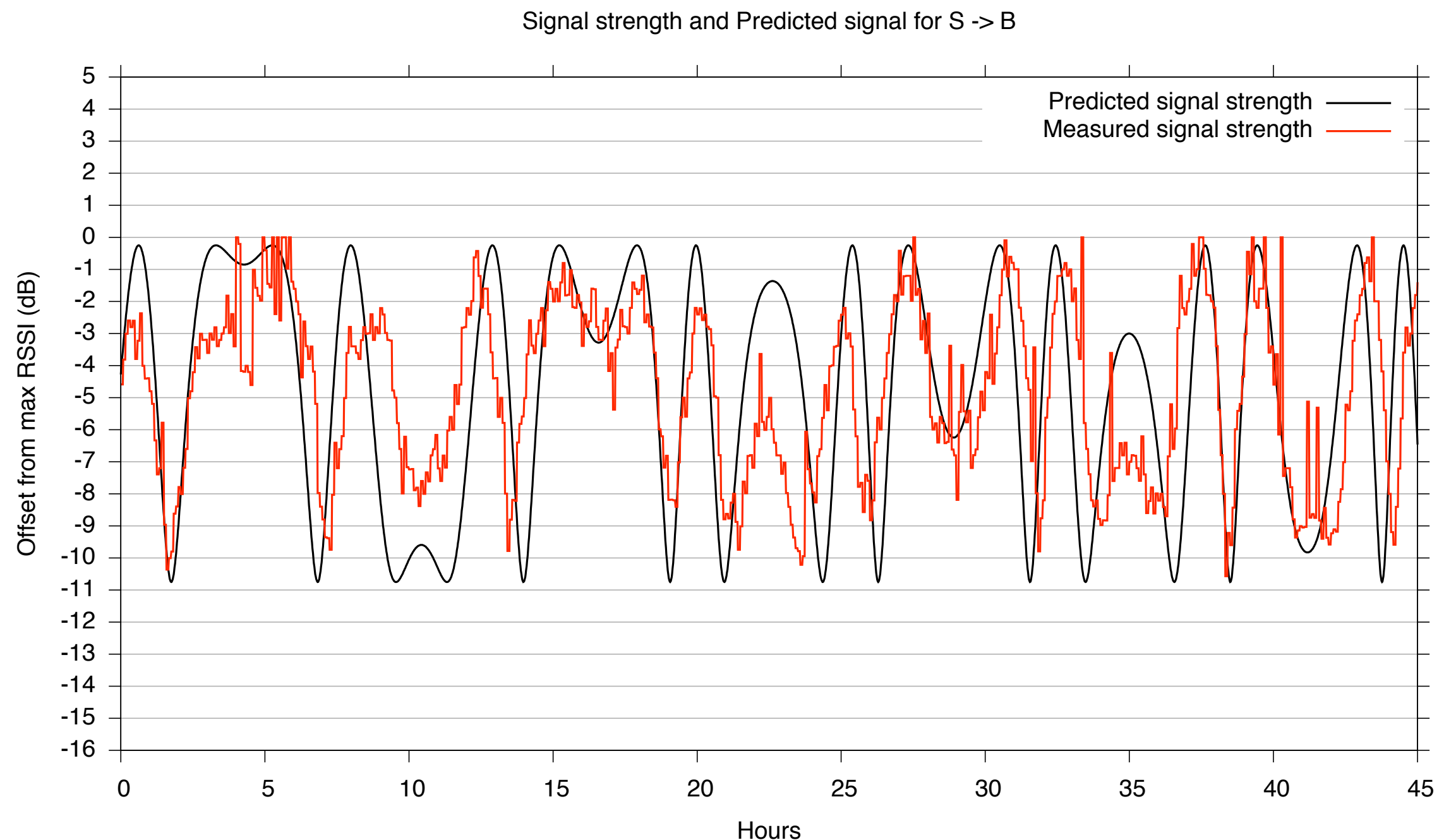
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- Most of our links travel **over the sea** for long distances (max: 19km) at low altitudes (40-100m)
- Noticed **severe periodic fluctuations** in the signal strength.
- Refractivity of “sea water” is 5000 times stronger than ground.
- The UK west coast has important tides, **ranging up to 7 meters.**



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- Noticed **severe periodic fluctuations** in the signal strength.
- Refractivity of “sea water” is 5000 times stronger than ground.
- The UK west coast has important tides, **ranging up to 7 meters.**
- **Modelling** the impact of tides on propagation over sea water.





# Direction #3: management of large WISP networks

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- The whole process of deploying a backhauling network for BWA is **complex**:
  1. Planning
  2. Configuration
  3. Monitoring
- We would like to develop a **framework** and a **tool suite** to:
  - ▶ identify the **best masts locations** and suggest an optimal topology
  - ▶ **automate** frequency planning, router configuration, routing balancing
  - ▶ **gather statistics** and present a minimal set of alarms to the network administration
- Additionally: in rural areas, each single link is inherently unreliable. We propose to study **Network-Embedded Applications (NEAs)** as a way to move applications from datacenters to the network routers improving reliability.

# Further details

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- Project website:  
[www.tegola.org.uk](http://www.tegola.org.uk)
- **Paper to appear** in MOBICOM 2008 workshop on “Wireless Networks and Systems for Developing Regions” (WiNS-DR).



# Questions?

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