Broadband Wireless Access for Rural Areas: The Tegola Project Experience

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And in partnership with

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Broadband Divide

- Between urban and sub-urban/rural areas
- In terms of coverage, quality and choice (cost)
- Due to several reasons: deployment costs, population density, location (remoteness, terrain), etc.
- Some figures…
  - About 3 million homes in the UK (covering ~10% of the population) get broadband speeds < 2Mbps (2009 BBC study)
  - 30% of EU rural population don't have broadband (EC, 2008)
  - 5% of US homes are in locations without broadband access and 36% of those w/o broadband cite cost as main reason (FCC, 2010)

Let Us Start with Two Basic Questions

1. How wide is the broadband divide?

   Where are the "notspots"?

2. What is the "right" technology or a combination thereof to bridge the divide?

   Key factors: provisioning cost per household and population density

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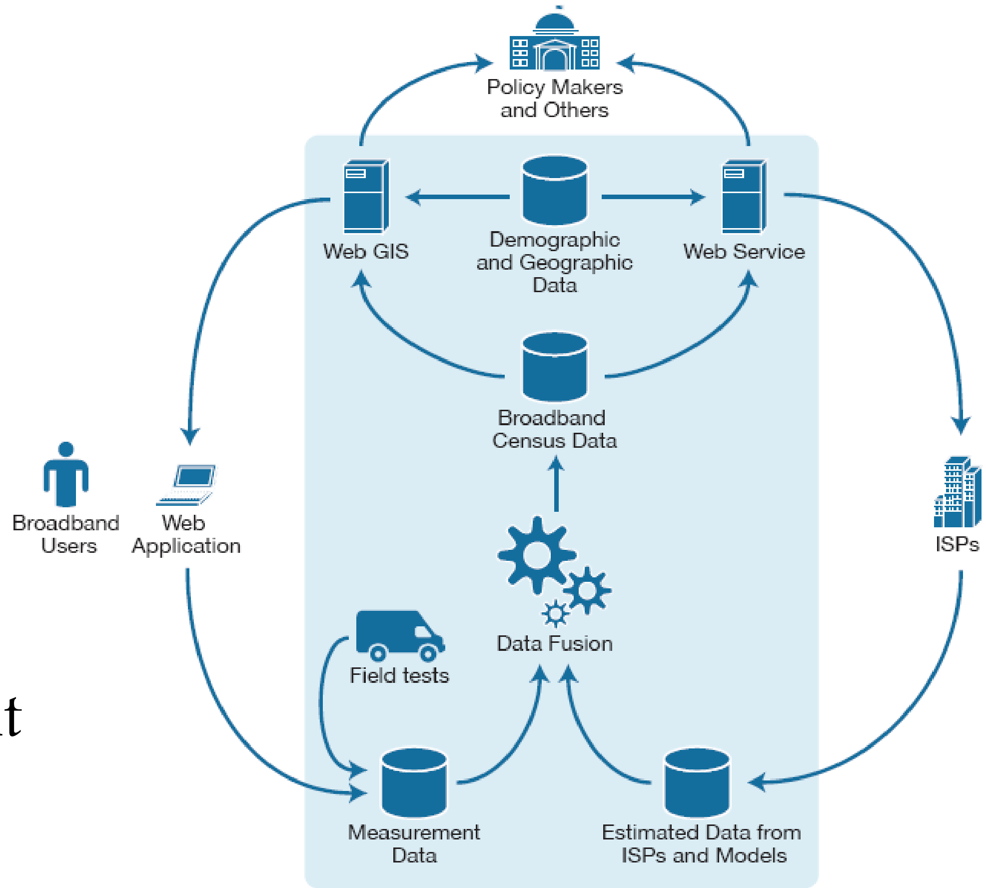
BSense: A System for Enabling Automated Broadband Census [MobiSys-NSDR'10]

- A framework offering incentives to all stakeholders to contribute
- A flexible software system based on open source tools
- Integrated approach using estimated and measurement data from different sources (e.g., ISPs, user tests)



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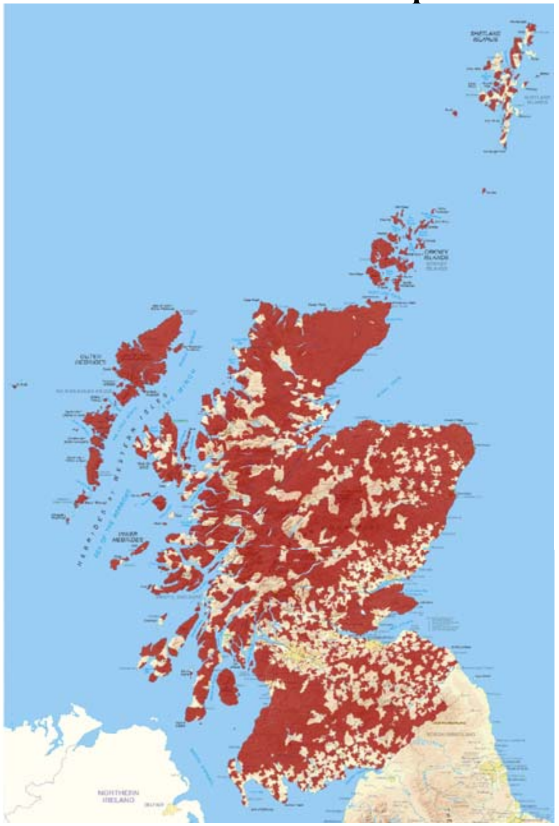
Broadband Access Technologies

- Wired
  - xDSL
  - Cable
  - Fibre (FTTx)
- Wireless
  - Terrestrial
    - 3G mobile broadband
    - WiMax
    - Licensed microwave (e.g., Connected Communities)
    - …
  - Satellite (e.g., SG supported Avanti)

BSense Case Study: A Broadband Census for Scotland
Notspot Maps

Threshold=512Kbps

Threshold=2Mbps



Threshold=8Mbps

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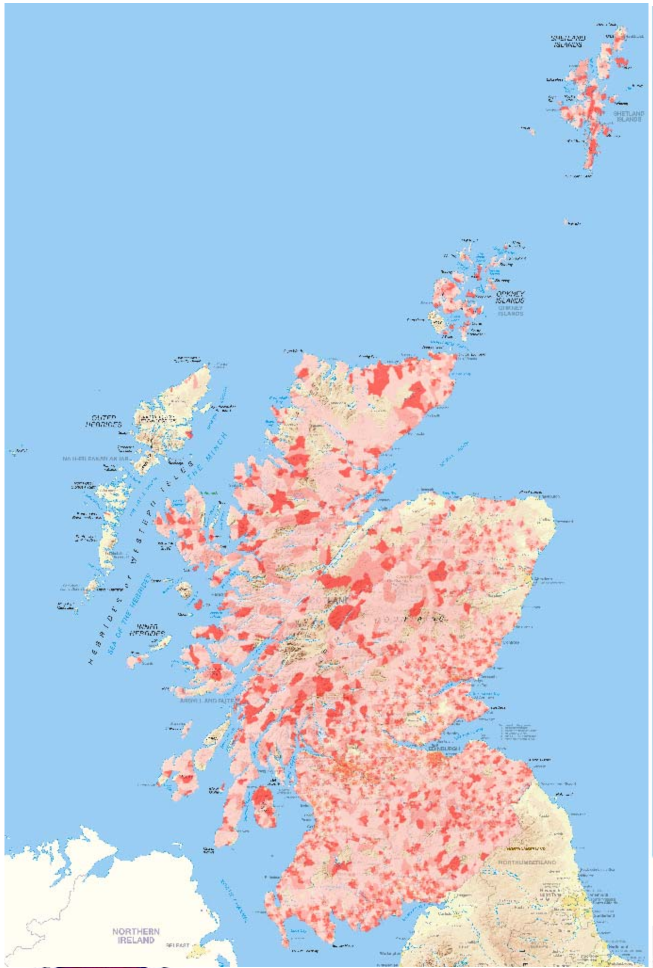
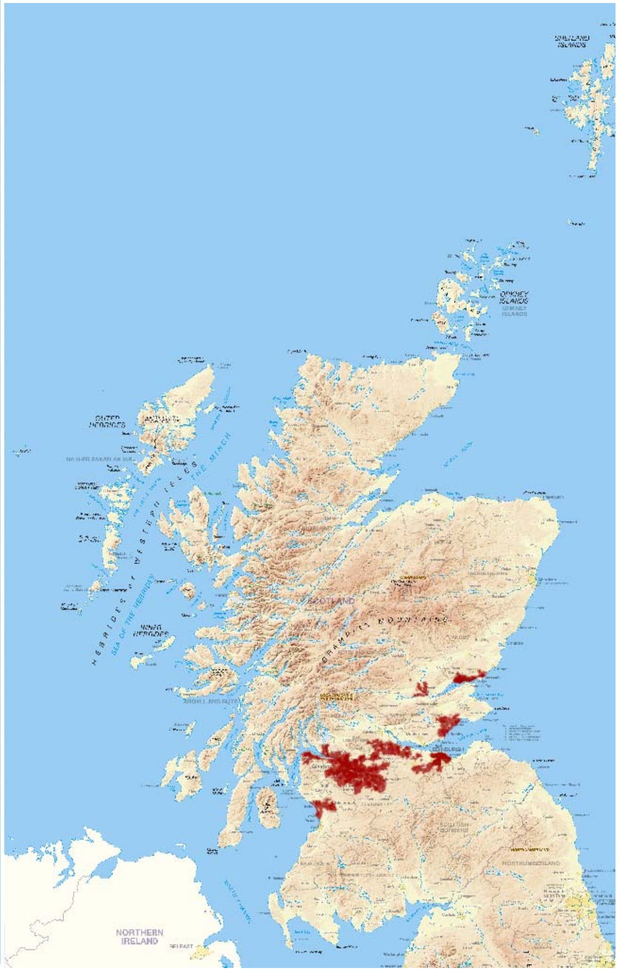
Estimated Broadband Coverage Maps w/ BSense

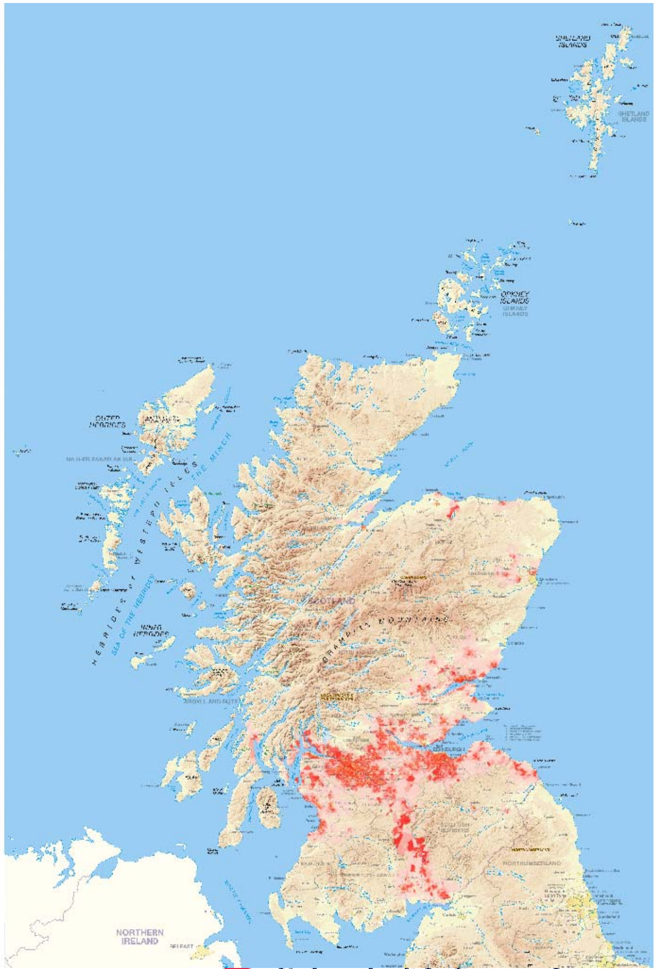
ADSL (BT Wholesale)



Cable (Virgin & Smallworld)



3G (Orange)



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Measurement Results for Satellite Users

	Download Speed (Mbps)	Upload Speed (Mbps)	Round-Trip Latency (ms)
Average	0.28	0.11	844.93
Standard Deviation	0.13	0.05	126.08
Min	0.06	0.03	732.85
Max	0.51	0.22	1187.54
Median	0.3	0.11	797.01

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Broadband Access Technologies

- Wired
  - xDSL
  - Cable
  - Fibre (FTTx)
- Wireless
  - Terrestrial
    - 3G mobile broadband
    - WiMax
    - Licensed microwave (e.g., Connected Communities)
    - Long-distance WiFi (e.g., Tegola)
  - Satellite (e.g., SG supported Avanti)

Long-Distance WiFi

- Commodity hardware and falling costs
- Little or no spectrum costs

Low CAPEX

- Latency not a significant issue for typical link lengths (few tens of kilometers)
- Rapid emergence of high-performance standards leveraging advances in wireless comms technology (e.g., 802.11n)
- Spectrum regulatory reforms also help (e.g., more unlicensed or opportunistically used spectrum)

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Tegola Testbed [MobiCom-WiNS-DR'08]

- Backhaul: network of 5 wireless relays interconnected by long-distance WiFi links
  - Redundancy in topology and links (dual polarized links)
  - Two backhaul relays self-powered

Unique characteristics:
- Over-water wireless links
- Presence of self-powered masts
- Active community participation
- Challenging weather and terrain

Peter's Goalpost Style Portable Mast Design Being Tested by Finlay, Our Onsite Engineer☺

Measurement Results for Tegola Users

	Download Speed (Mbps)	Upload Speed (Mbps)	Round-Trip Latency (ms)
Average	8.85	8.5	85.61
Standard Deviation	4.86	5.15	54.3
Min	1.38	2.25	37.68
Max	18.45	16.05	246.59
Median	7.9	9.08	64.84

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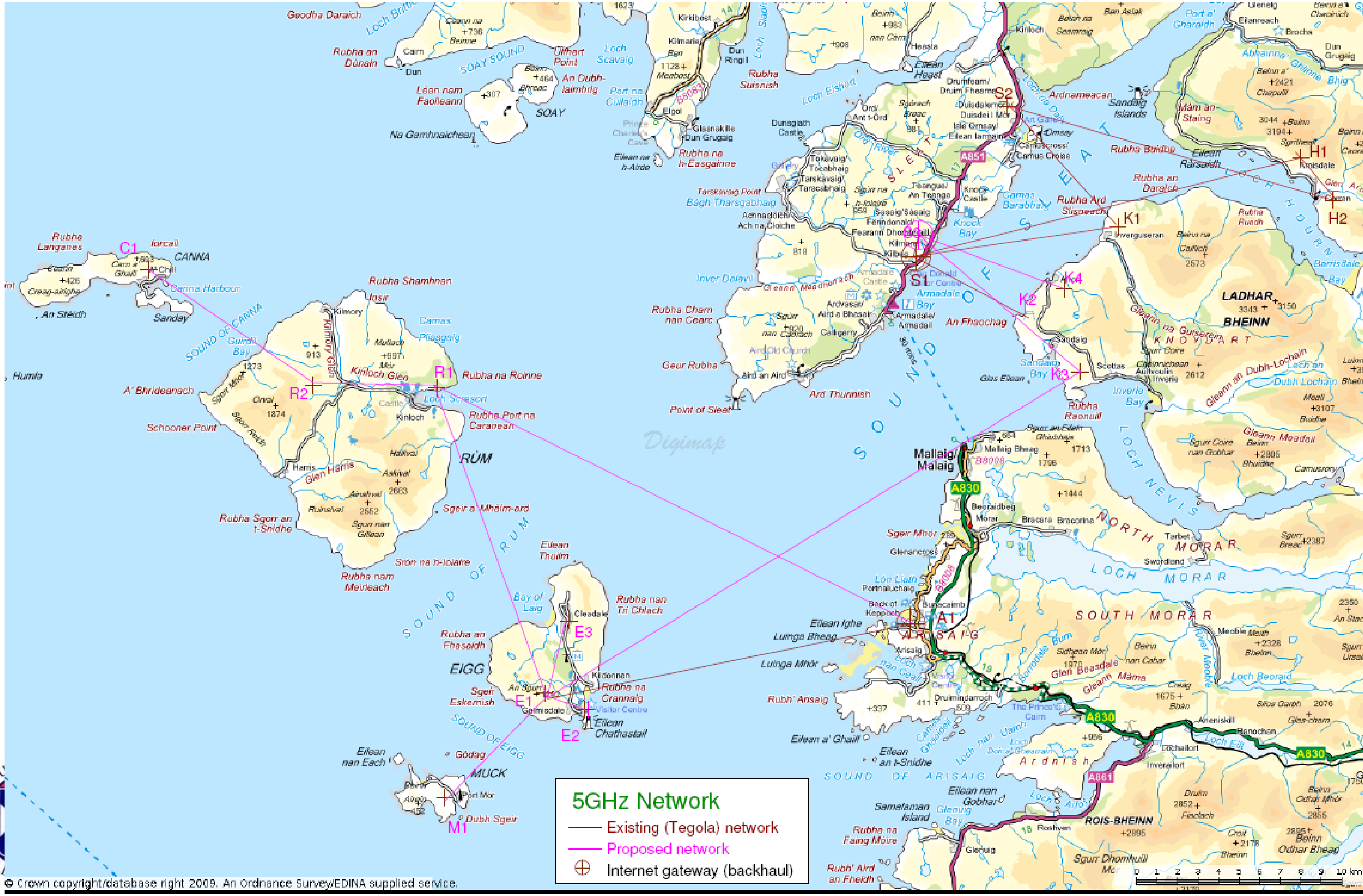
Tegola ver. 2.0 in the Works
(incl. Small Isles and S/SW Knoydart)



Tegola Project: Research Agenda

- Broadband mapping: BSense [MobiSys-NSDR'10]
- Network planning
- Network management: Stix [MobiCom'10]
- Network protocols and adaptation mechanisms
  - Link adaptation for reliable communication [INFOCOM'10]
  - Power management for lowering the cost of self-powered relays [SOSP-NSDR'09]
  - Adaptive spectrum management
- Characterization of rural Internet usage

Link Adaptation for Reliable Communication

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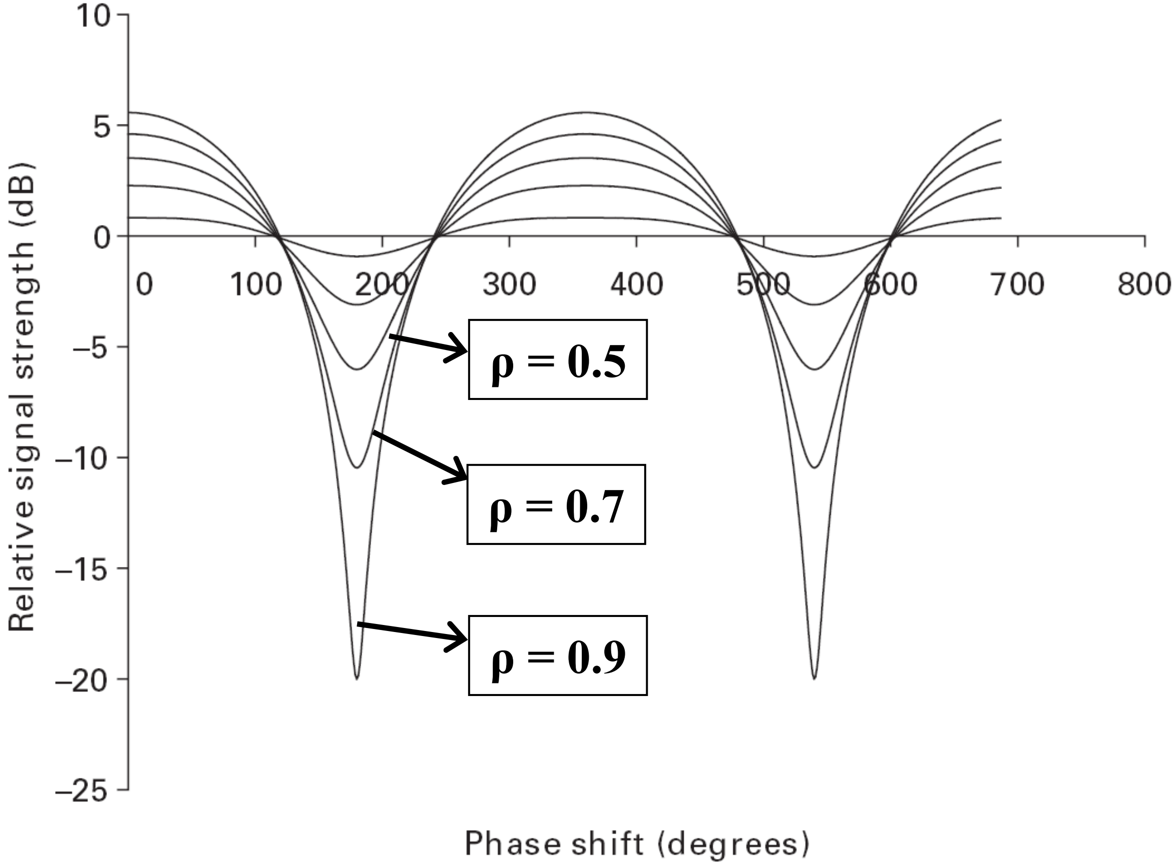
Tegola Network Map

- All backhaul wireless links at least partly over tidal sea water

The Tidal Fading Problem

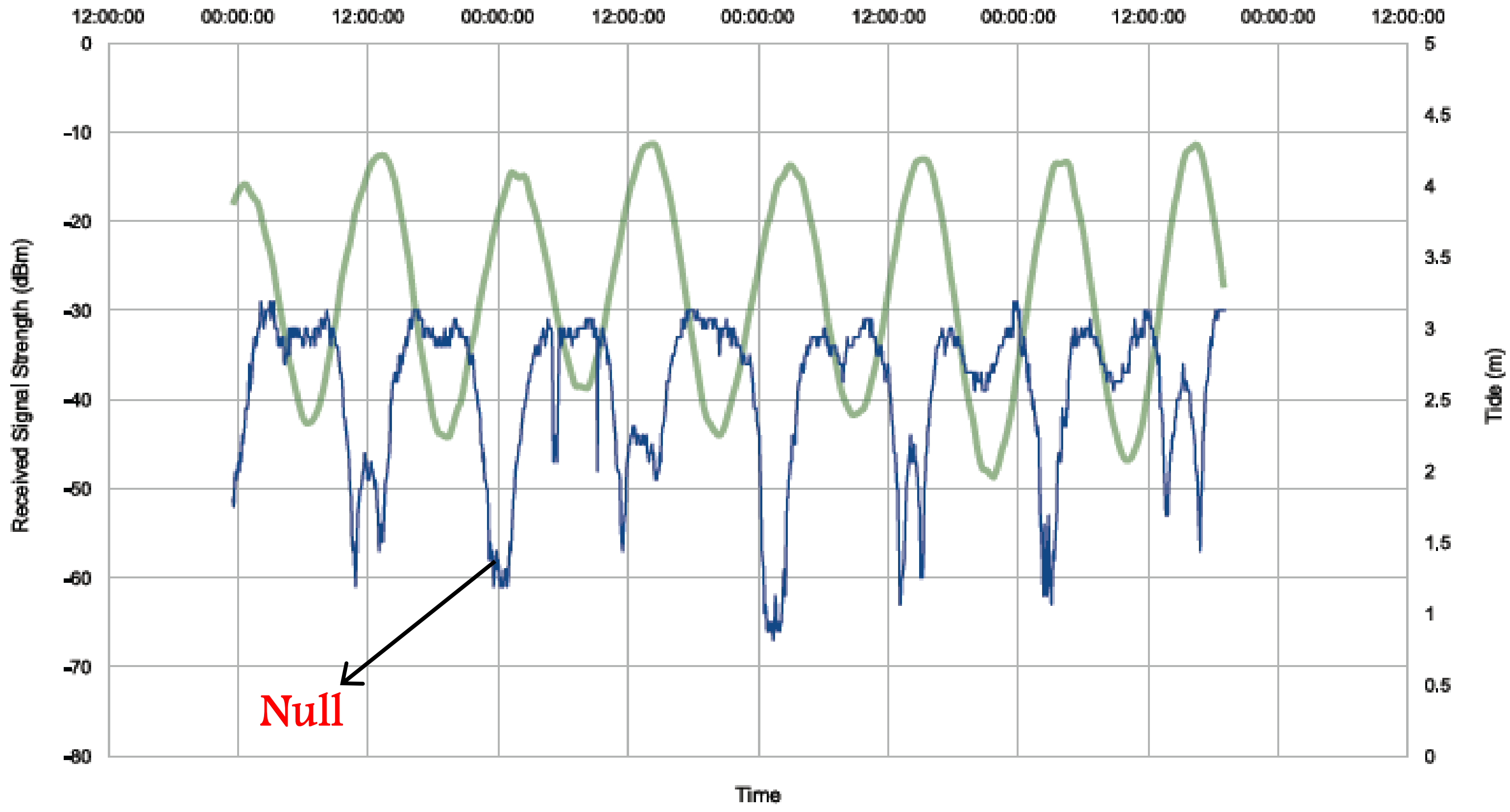
- Tidal water acts as a time-varying reflecting surface
- Two-ray model: reflected ray interferes with the direct ray

Relative phase shift causes
constructive or
destructive interference



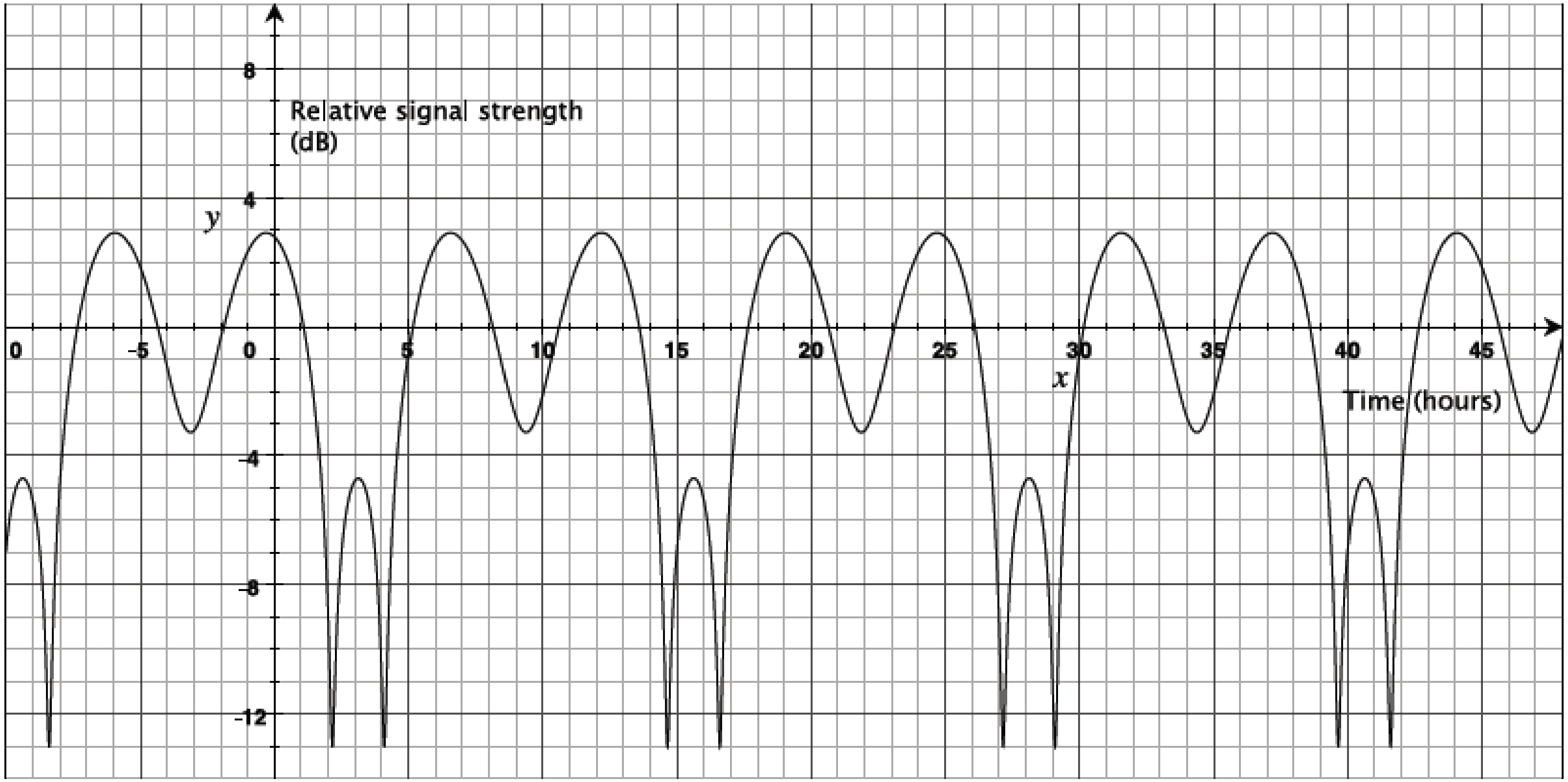
Actual Measurements

- Signal strength recorded on the Arnisdale test link



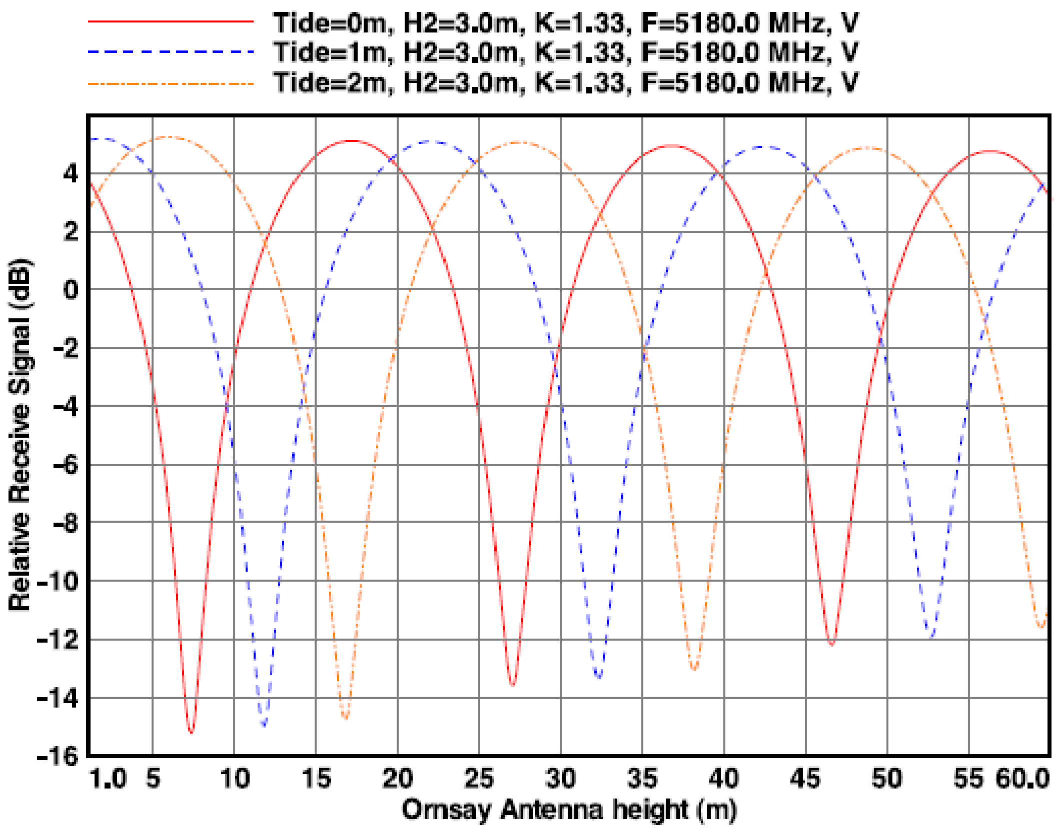
Signal Strength Variation Using Geometric Model and Simulated Tide

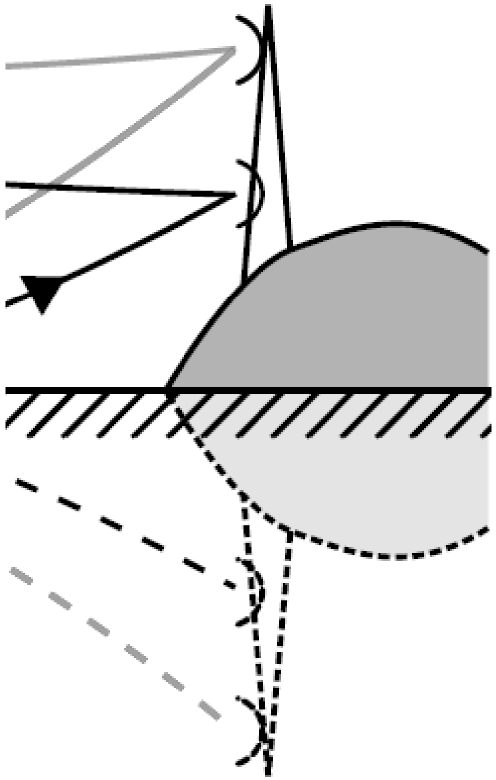
- Signal strength against time for Arnisdale test link. d = 1570m, h1 = 40m, h2 = 2m, f = 2.4GHz, ρ = 0:95, ht = sin(2x/12.5) + 1



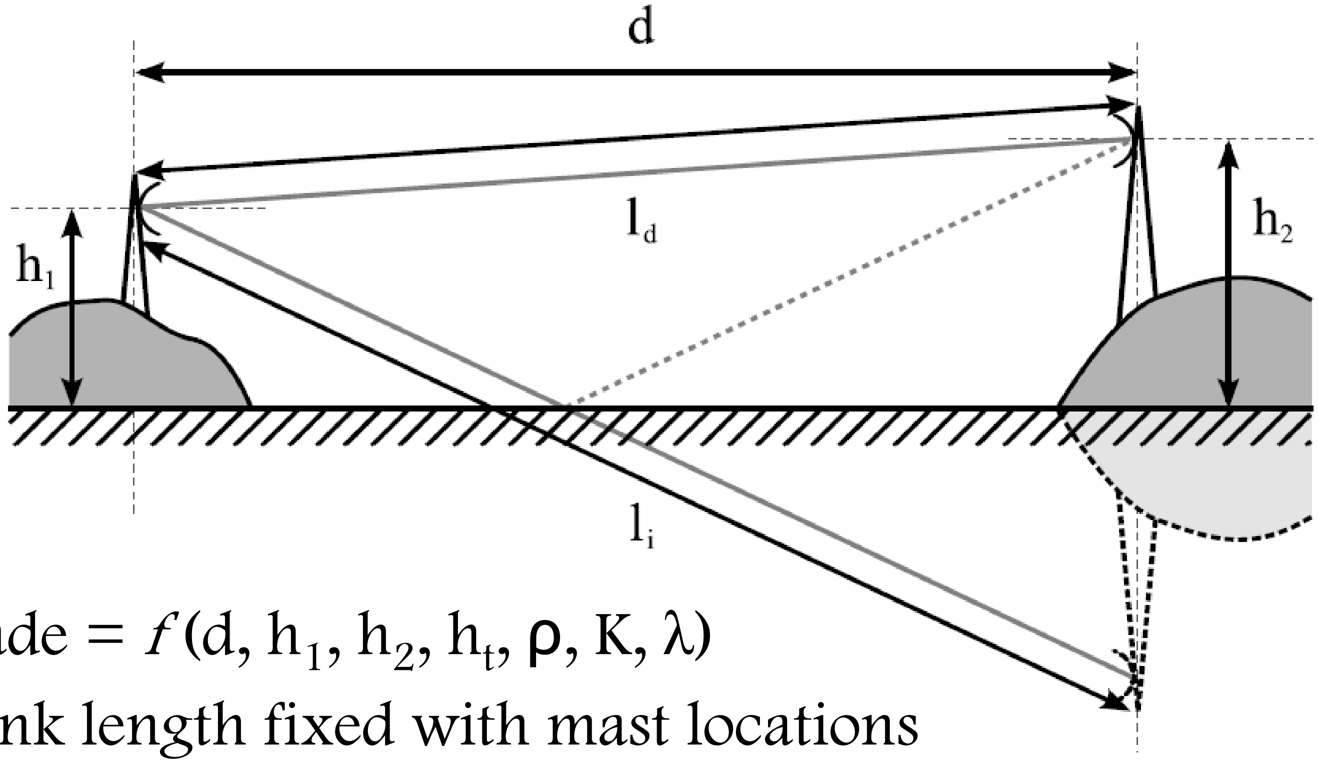
Standard (Industry) Solution – Spatial Diversity

- Use two receive antennas vertically spaced apart s.t. both of them do not experience a null at same time
- Higher cost and deployment complexity





Our Solution – *Slow* Frequency Hopping (SFH)



- Fade = f(d, h_1, h_2, h_t, ρ, K, λ)
- Link length fixed with mast locations
- Antenna heights expensive to control
- Tide (h_t), reflectivity (ρ) and air pressure gradient (K) cannot be controlled
- However, frequency (c/λ) can be controlled

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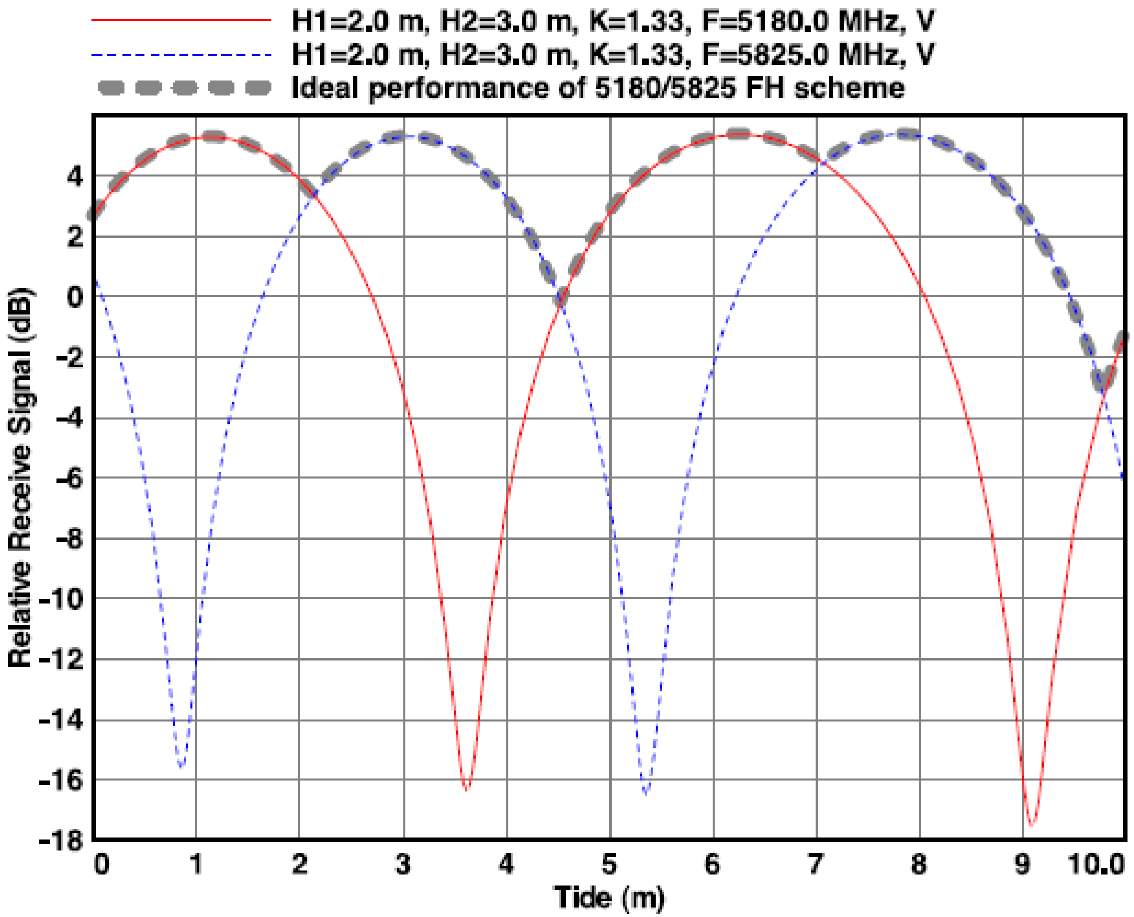
Potential Benefit of SFH to Mitigate Tidal Fading



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SFH [INFOCOM'10]

- A promising technique for improving reliability on over-water links subject to tidal fading
- Software only solution
  - No extra hardware is required and it can be retrofitted into existing networks
- On-going work:
  - Validating modelling and simulation results using field measurements over test links in the Tegola network
  - Experimentation with different SFH algorithms
  - Compare with MIMO (802.11n)

Summary

- Long-distance WiFi based technology approach
  - Network of wireless relays interconnected by long-distance directional links
- Deployed a testbed in the northwest of Scotland [MobiCom-WiNS-DR'08]
- Research agenda:
  - Broadband mapping: BSense [MobiSys-NSDR'10]
  - Network planning
  - Network management: Stix [MobiCom'10]
  - Network protocols and adaptation mechanisms
    - ➢ Link adaptation for reliable communication [INFOCOM'10]
    - ➢ Power management for lowering the cost of self-powered relays [SOSP-NSDR'09]
    - ➢ Spectrum management

References

1. Stix: A Goal-Oriented Distributed Management System for Large-Scale Broadband Wireless Access Networks, *In ACM MobiCom 2010.*
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Thanks!