IPv6 and Low-Power Mesh Nets

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Outline

- Ad hoc networking – networking *really* anywhere
- Mesh Networking – serving communities in a new way
- Low-Power Mesh Networking – what is it?
- Current approaches
- Our recent development

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Ad Hoc Network characteristics

- peer-to-peer
- multihop
- dynamic
- *Really* “anytime, anywhere”

- zero-administration
- low power
- autonomous
- autoconfigured

But, most of these have exceptions!

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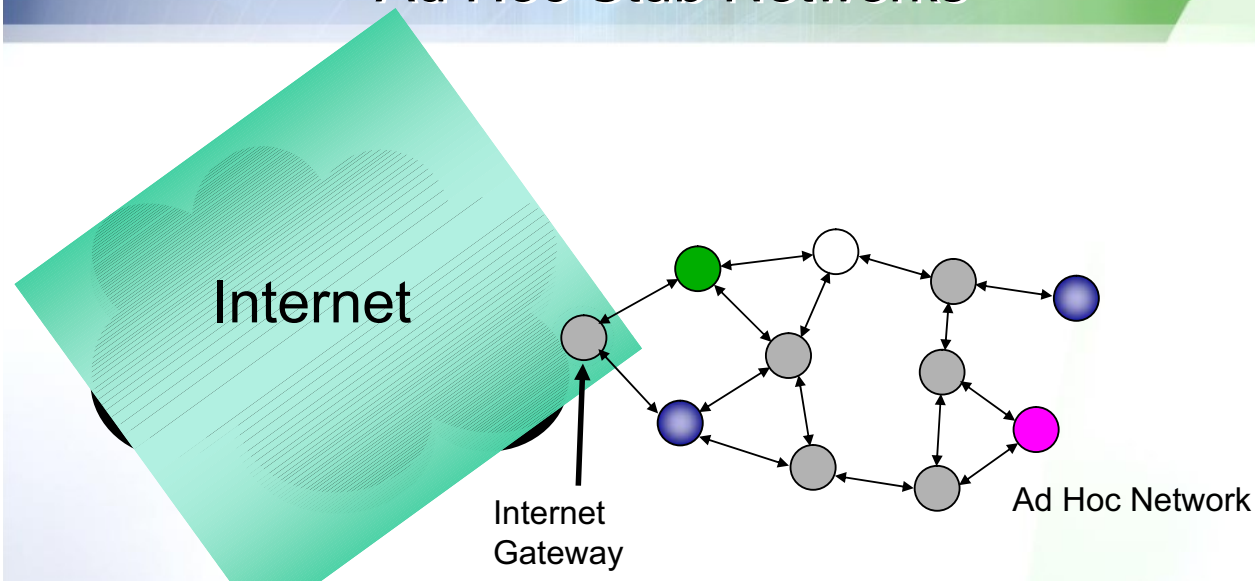
Ad Hoc Stub Networks



- If any node has access to the Internet, then all nodes can have access.

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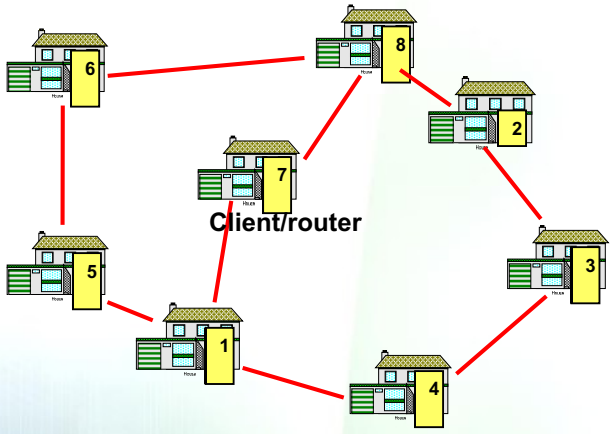
Mesh Networks

- We can view mesh as a special kind of ad hoc network
  - Some designated stable points (+power)
  - Wireless ad hoc nodes freely moving
- Mesh points *may* be Internet gateways
  - Or, mesh may be completely disconnected
- Mesh points are natural clusterheads



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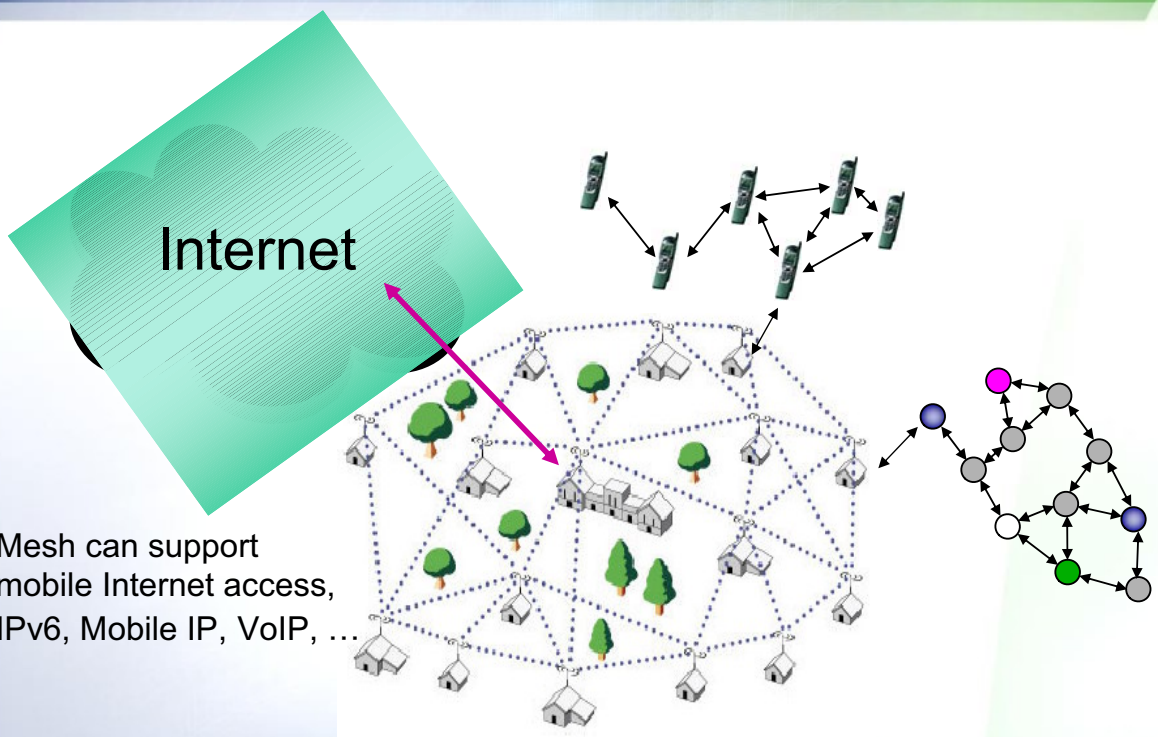
Mobile Internet Mesh Access



Mesh can support mobile Internet access, IPv6, Mobile IP, VoIP, …

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Municipal mesh is encountering obstacles

- Seen as a community service
- Can support VoIP and reasonable Internet access…
- Being deployed in many major cities
  - Philadelphia, Mountain View, Long Beach, …
- Prompting bitter regulatory battles
  - Operators claim unfair competition
  - They paid billions for the chance to offer “similar” service
- How often will the municipal mesh be upgraded?
  - Who will maintain?
  - 802.11* technology is moving quickly
  - Governments do not always move quickly!
- Who will complain, and to whom, if it does not work?
- Will WiMax change the rules again?
  - Intel wants to repeat the success of Centrino, via WiMax

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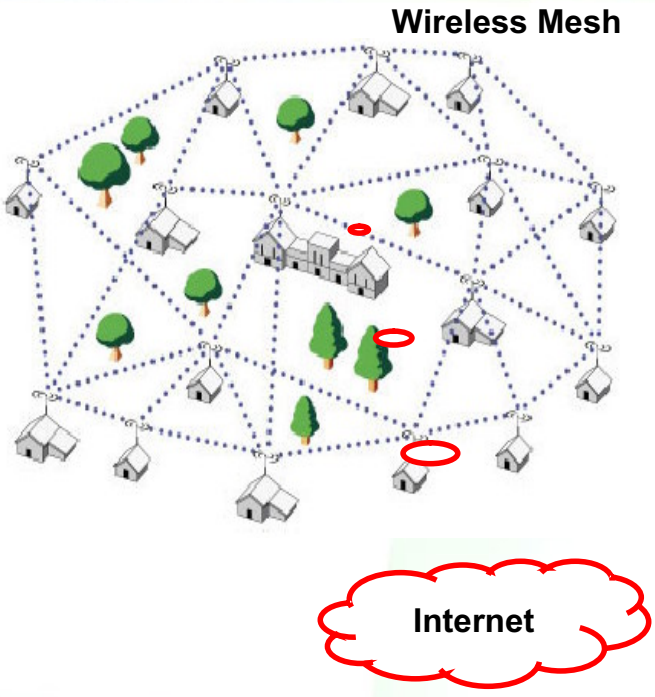
Case study: paradigm shift in Africa?

- From operator/telco model to ***user-deployed and user-owned grassroots infrastructure***
  - Community owned
  - Each node is a client & router
  - No monthly subs or usage fee for local ‘calls’ – infrastructure belongs to the users
- True “common grazing ground” - free information infrastructure
- Last mile => First mile
- Also worthwhile: www.airjaldi.com and their experiences in Dharamsala, India



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Electricity distribution

Perhaps a half-million villages, mostly with inadequate power…

Ad hoc and Mesh Networking can offer communications with more efficient power utilization

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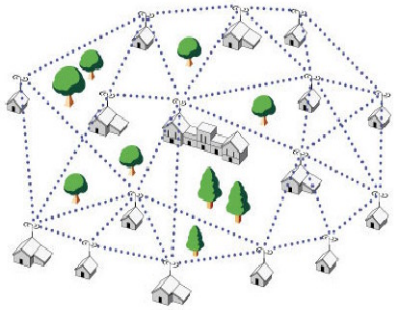
Bottom-up approach; aggregated demand



- "Wireless Africa" paradigm shift:

  …Top-down changed to bottom-up…
- This seems to be what is needed to extend access to the next billion users
- Last mile support is the biggest headache for operators
- What if: operators only provided backhaul in rural areas?
- What if: demand could be aggregated?
- We have good enough technology now...
  - Self-provision; shared use of broadband entry point
- Harness the strong African sense of community!
- "Once e-mail is supplied, it can never be taken away"

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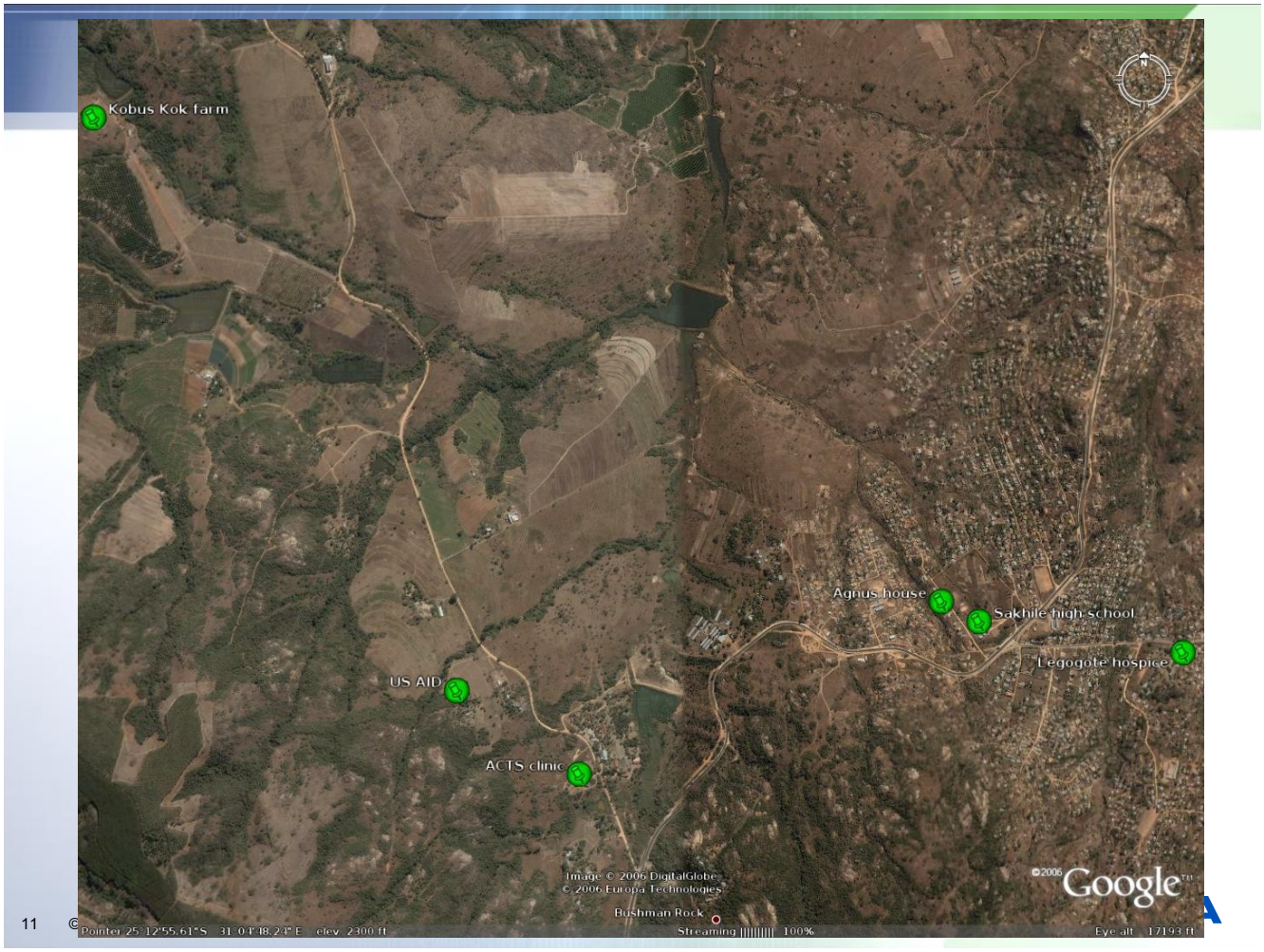
Kobus Kok farm
Agnus house
Sakhile high school
Legogote hospice
US AID
ACTS clinic
Image © 2006 DigitalGlobe
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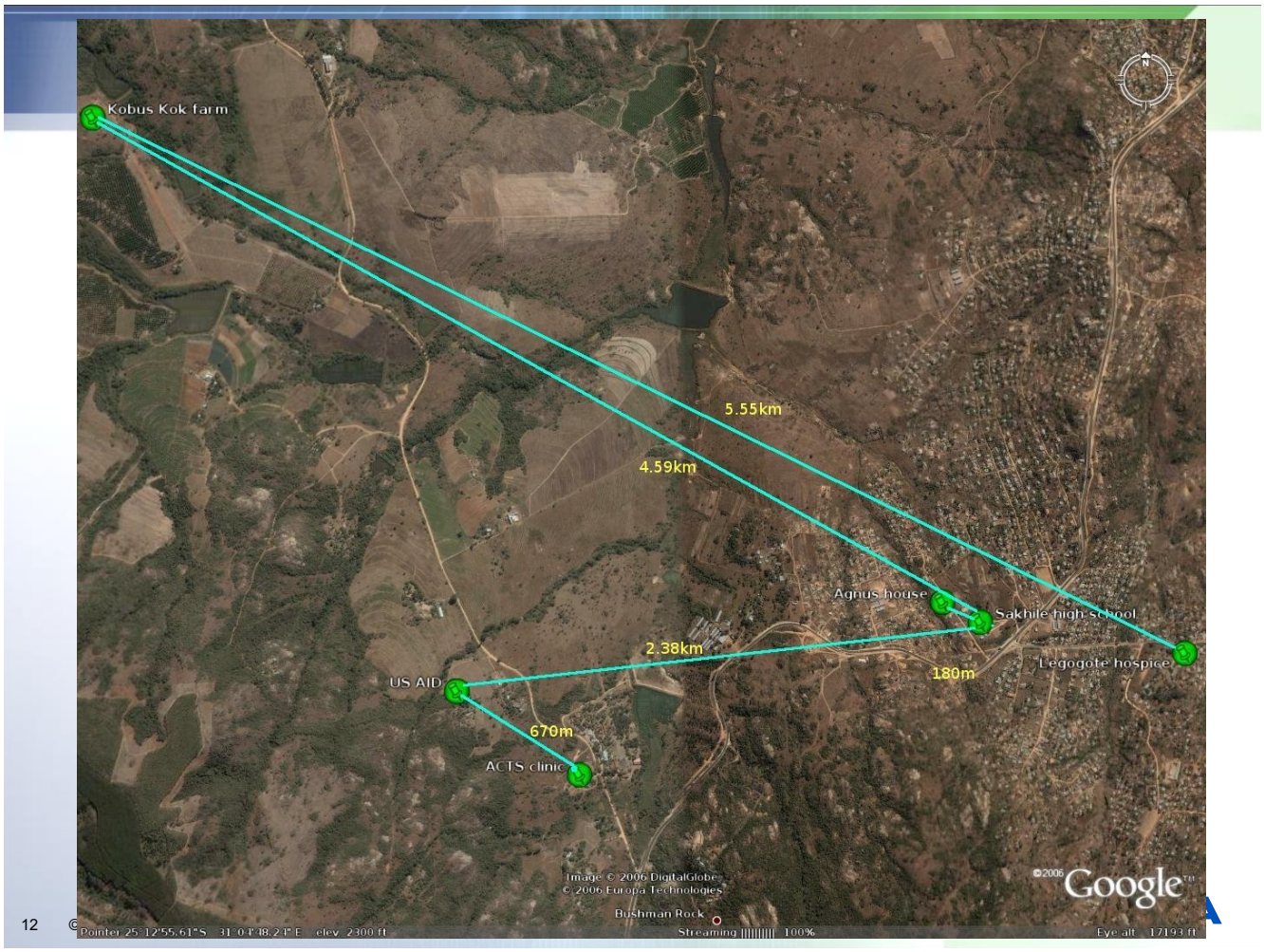
Bushman Rock
Pointer 25°12'55.61"S 31°0'18.21"E elev 2300 ft
Streaming 100%
Eye alt 17193 ft


Kobus Kok farm
5.55km
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Agnus house
Sakhile high school
2.38km
180m
Legogote hospice
US AID
670m
ACTS clinic
Image © 2006 DigitalGlobe
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Technical approaches to managing power usage

Much of the world has insufficient access to robust power

In order to extend the Internet to the next billion users, some new approaches are needed to deal with this problem!

- Turn off network elements that are not in use (or, more precisely, operate them at low duty cycle)
- Mesh and ad-hoc seem economical compared to GSM base stations plus phones
- Reduce number of signaling operations
  - Proactive vs. Reactive
    - 802.11s uses AODV-like protocol
  - More efficient flooding
- 6lowpan IETF work can further reduce power (Zigbee, Wibree)
- Delay-Tolerant Networking can help overcome power outages

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Traditional (Proactive) Routing Methods

- Advantages of using routing protocols:
  - Self-Starting
  - Multi-Hop
  - Dynamic topology
- Link-State (*Dijkstra's* shortest-path algorithm)
  - Complete topology stored
  - OSPF (RFC 1583)
- Distance-Vector protocols (*Distributed Bellman-Ford*)
- Single metric: number of hops to destination
  - But this isn't really appropriate, esp. for 802.11

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On-Demand Routing Protocols

- Eliminate route table updates for routes that are not used
- Fewer control packets:
  - → Better scalability
  - → Reduced congestion
  - → More robust protocol action
- Less frequent control packets → reduced processing requirement
- Even more localization for topology changes if distance vector
- Also can be made to work for link-state

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On-Demand Routing, cont.

Downsides:

- Do not abort application until after after Route Discovery attempt
  - In other words, disable traditional ICMP behavior
- Latency → longer application launch times
- Route Discovery uses flooding/broadcasts

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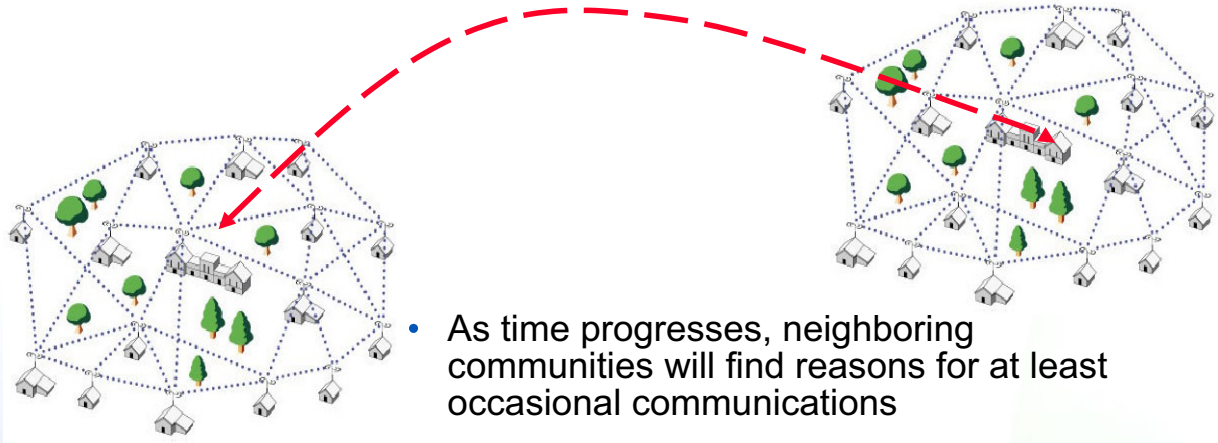
Enabling contacts between communities



- As time progresses, neighboring communities will find reasons for at least occasional communications
- If each community makes use of IPv6 addresses from the range of Unique Local Addresses, dangers of address overlap will be minimized
- No additional network administration needed!

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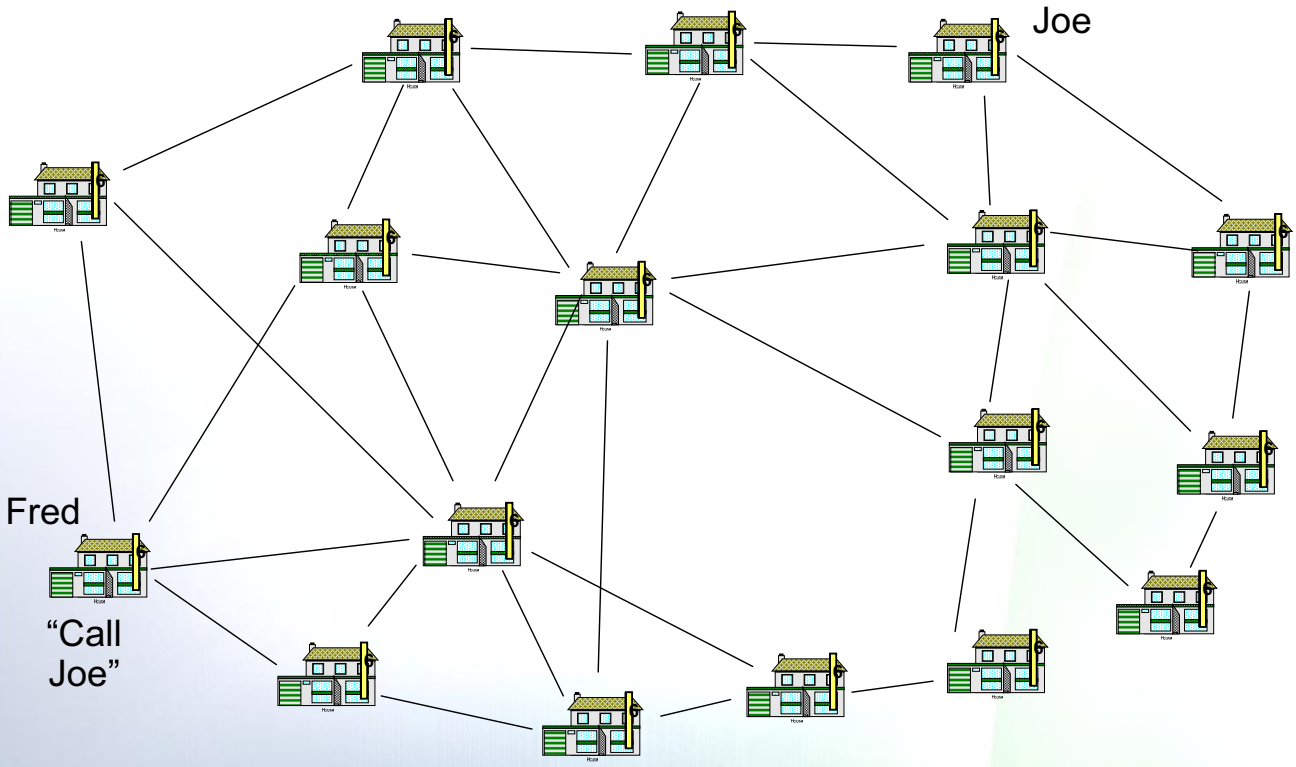
An example mesh – the value of a backbone



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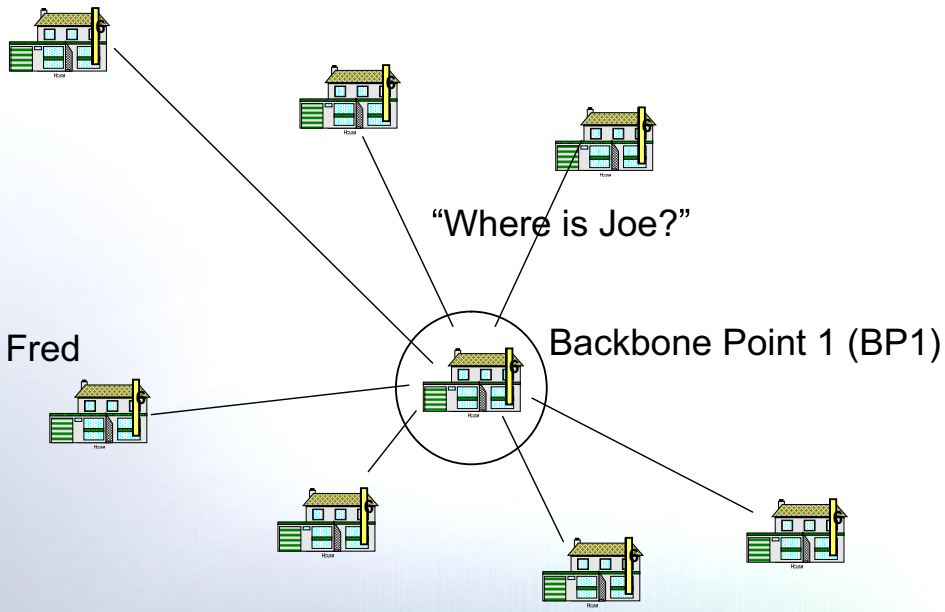
Only backbone points retransmit broadcasts



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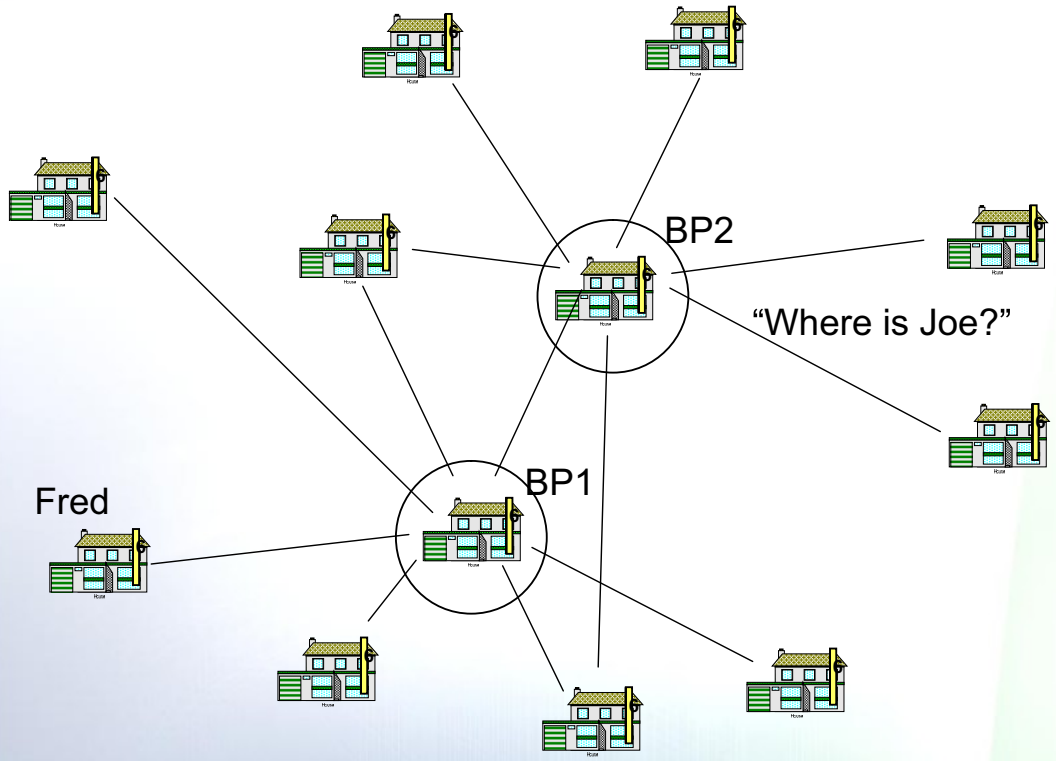
Mesh points covered by backbone points BP1, BP2



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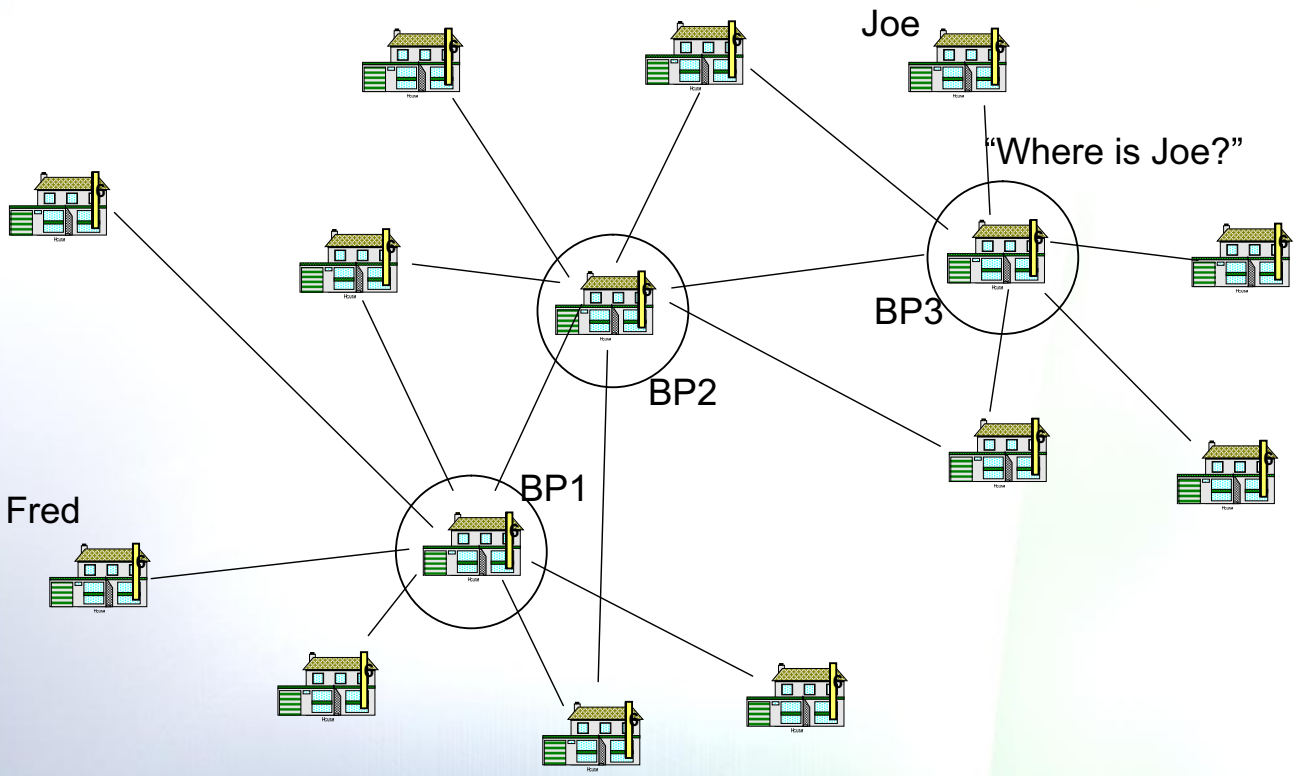
Mesh points covered by BP1, BP2, BP3 (we found Joe!)



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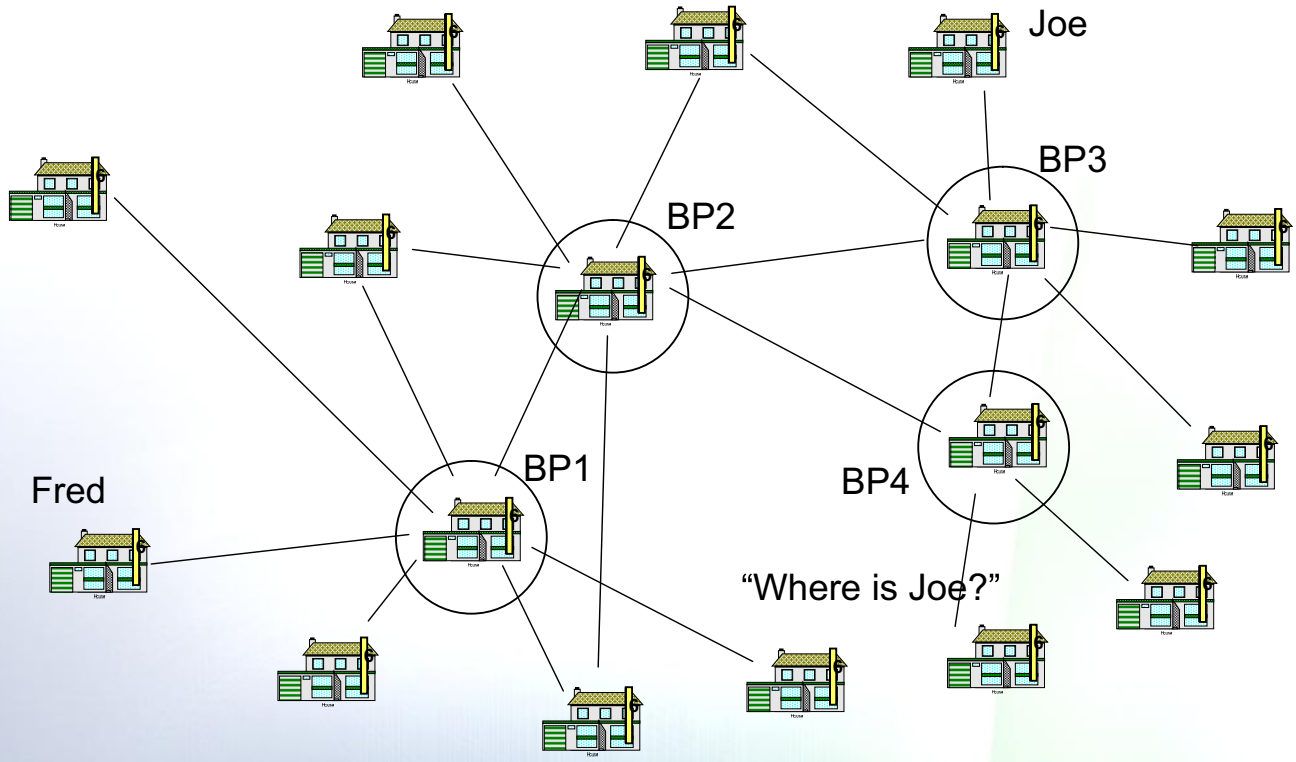
But, well, the discovery process still goes on



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Advantages of maintaining a backbone

- Huge win: fewer control messages
- ➔ reduced congestion, higher throughput
- Also, the main point for our Wireless Africa goals – reduced power
- Non-backbone nodes are great candidates for low-duty cycle operation (i.e., power shutdown with periodic wakeups)
- Must keep in mind, though, that mesh points can support many clients that are not mesh points (e.g., associated STAs, ad hoc networks).
- Backbone nodes are well-situated for managing more sophisticated channel allocation schemes

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Disadvantages of backbone maintenance

- Signaling needed for identifying the backbone mesh points
- Typically, most routes pass through mesh points – likely causing unequal power drain
- When media broadcast is locally unreliable (e.g., 802.11), the smaller number of broadcasts occasionally does not provide enough redundancy
- May not offer much benefit for *low-degree* mesh networks
  - "low-degree" – i.e., number of neighbors per mesh node.

A large body of research is currently underway to ameliorate these disadvantages, but already the advantages are known to greatly outweigh the disadvantages

It is also possible to use iterated unicast to replace broadcast, for higher data rates and potentially reduced power consumption

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Low-power Mesh for Wireless Africa

- Our current project
  - Motivated by likely collaboration with Meraka Institute, South Africa
- Currently targeting Meraki Corp. (Mountain View, CA) access points
  - 3 Watts power
  - $50 (but price is going up)
- Uses OpenWRT software (open source, Linux-based)
  - Specifically, Kamikaze 0.7 release, Atheros target
  - IPv6 is part of the basic software distribution
  - Now available: on-demand/disruption tolerant routing
- Searching for good solutions for solar power
  - A $3,000 solar panel is *NOT* a good solution
  - Important: need a way to check for available energy stored

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Autonomous Computing

From Autonomic Networking conference (Sep. 2006):

- self-organising
- context-aware
- self-governing

Network organization becomes an internal affair

Ideal framework for thinking about solutions for Wireless Africa, especially because autoconfiguration is closely involved

Motivated by mobility and ever-more-powerful devices

- Brute force methods only work for static devices

Thought experiments:

What will *you* do with 100 Gbytes in your pocket during 2009?

What would a community do with numerous terabytes?

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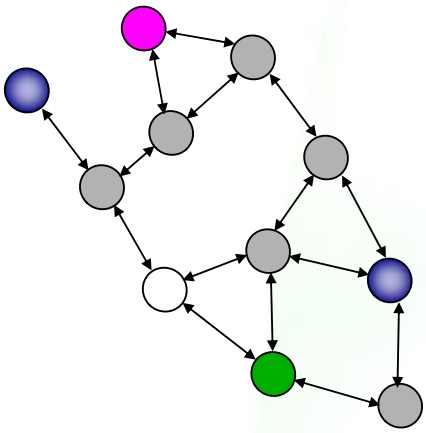
IETF autoconf working group

Charter: Automatic Address Configuration for MANETs IPv6 only)

First: need a good understanding of the IPv6 addressing model!

One idea: re-use basic route discovery mechanism from well-known [manet] routing protocols:

1. Pick a random address
2. See if it is “reachable”
   - i.e., a route to it can be discovered
3. If not, the address is presumed to be unused



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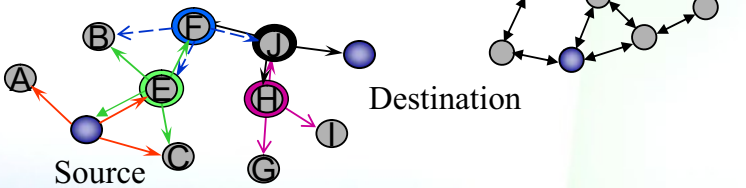
Address Discovery

- IPv6 is astronomically more likely to work with random addresses
- Automatic configuration is crucial for rural deployments
- There are many details about doing route discovery efficiently
- But, they all assume the nodes in the network have addresses!
- For “bootstrapping”, reserve a set of temporary addresses.
  - This also works far, far better with IPv6

- Other approaches also work a LOT better with IPv6
  - (e.g., buddy list sharing of address pools)



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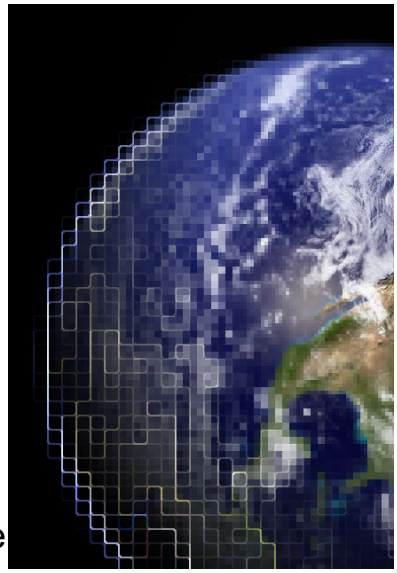
Summary and Conclusions

Low-power Wireless Mesh and Ad Hoc networking can extend the network to new billions of users



IPv6 should be the big enabler

→ Autonomous rural communities

→ Unambiguous addressing across neighboring regions villages

→ Automatic configuration makes networking available even for people without expertise

New techniques for power saving along with open source software and economical hardware are making the difference today

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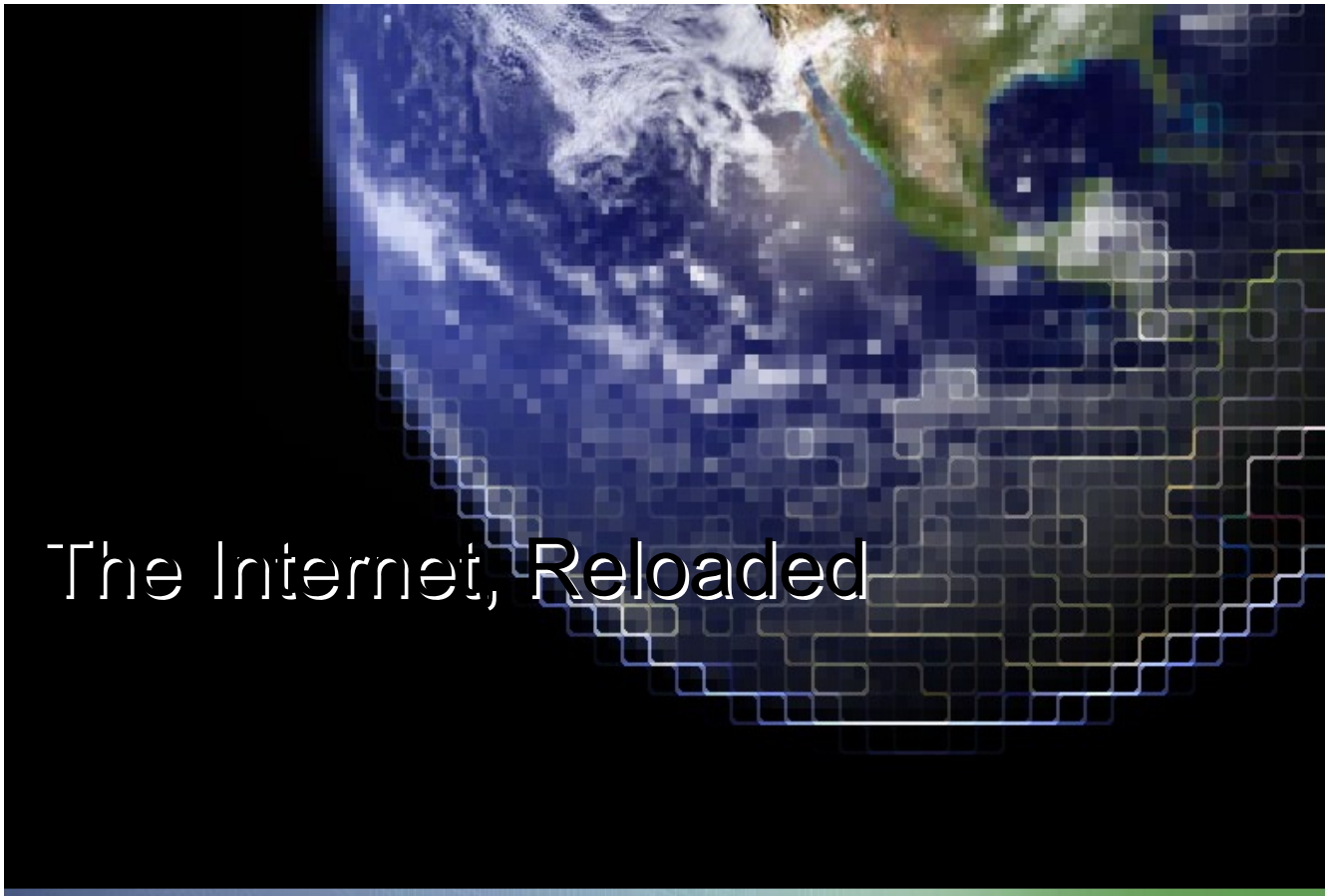

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