UNIVERSITY OF CAMBRIDGE
Computer Laboratory

Digital Epidemiology: Challenges in Data Collection in Developing African Countries

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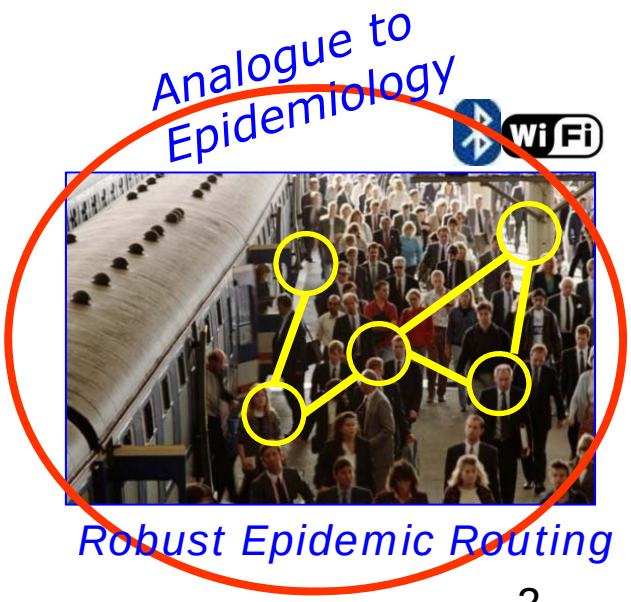
Spread of Infectious Diseases

- Thread to public health: e.g., 

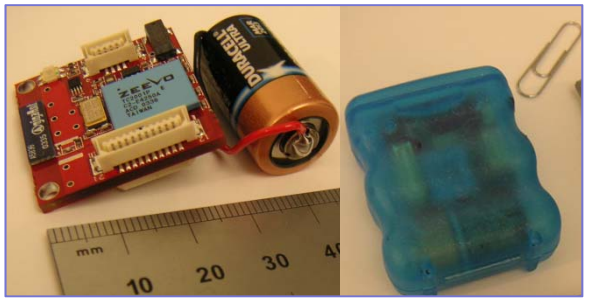
SARS, AIDS, Ebola
- Current understanding of disease spread dynamics
  - Epidemiology: small scale empirical work
- Real-world networks are far more complex
  - Advantage of real world data
  - Emergence of wireless technology for proximity data
  - Post-facto analysis and modelling yield insight into human interactions

Modelling realistic infectious disease spread/prediction



Electronic Proximity Sensing

- Sensors
  - Bluetooth Intel iMote
  - Zigbee



- RFID Tags

  - UHF Tag Alien ALN-9640 - "Squiggle®" Inlay
  - OpenBeacon active RFID Tag

- Mobile Phones
  - FluPhone Application
  - GPS, Google latitude

- GPS Logger
- Online Social Networks
  - Twitter, Facebook, Foursquare...

FluPhone Project

- Understanding behavioural r
  disease outbreaks
- Proximity data collection usi
  general public in Cambridge

https://www.fluphone

FluPhone UNIVERSITY OF CAMBRIDGE UNIVERSITY OF LIVERPOOL

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FluPhone Study

This is the home page for the FluPhone study. A study to measure social encounters made be
their mobile phones, to better understand how infectious diseases, like 'flu, can spread betwee

This study will record how often different people (who may not know each other) come close to
part of their everyday lives. To do this, we will ask volunteers to install a small piece of software
on their mobile phones and to carry their phones with them during their normal day-to-day activ
will look for other nearby phones periodically using Bluetooth, record this information and send
research team via the cellular phone data service. This information will give us a much better u
often people congregate into small groups or crowds, such as when commuting or through wor
activities. Also, by knowing which phones come close to one another, we will be able to work
people actually are, and how fast diseases could spread within communities. We are also aski
inform us of any influenza-like symptoms they may experience during the study period, so that

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4 May 2011 Last updated at 17:49

FluPhone app 'helps track spread of infectious diseases'

A mobile phone application could help monitor the way infectious diseases such as flu are spread.

The FluPhone app was developed by researchers at the University of Cambridge Computer Laboratory.

Volunteers' phones filled with the app "talk" to each other, recording how many people each "infected subject" meets during an imaginary epidemic.

The FluPhone app tracks volunteer "infected subjects" using Bluetooth technology

The university is one of seven institutions working on the study to reduce the impact of epidemics.

The FluPhone app uses Bluetooth technology to anonymously record interaction between volunteers involved in the study.

When mobile phones come into close proximity, that fact is recorded and data is sent automatically to the research team.

Related Stories

Web surveillance maps global disease trends

'Valuable insight'

Professor Jon Crowcroft and Dr Eiko Yoneki, co-principal investigators of the study, said they believed the collected data could be used to simulate social interaction during a real epidemic or pandemic.

A three-month FluPhone pilot study, using a basic version of the app, was conducted in Cambridge in 2010.

Dr Yoneki said: "The data was a valuable insight into how human communities are formed, how much time people spend together, and how frequently they meet.

"Such data show complex network-like structures, which is very useful for understanding the spread of disease."

Prof Crowcroft explained epidemiologists traditionally monitor how a disease spreads by asking patients to keep diaries of their movements and social contacts.

"That's very heavy-going and people often forget to do it, or forget who they've met," he said.

The FluPhone app was, he explained, a more reliable way to record contact between "infectious subjects".

Monitoring behaviour during a simulated epidemic could help prevent the disease spreading

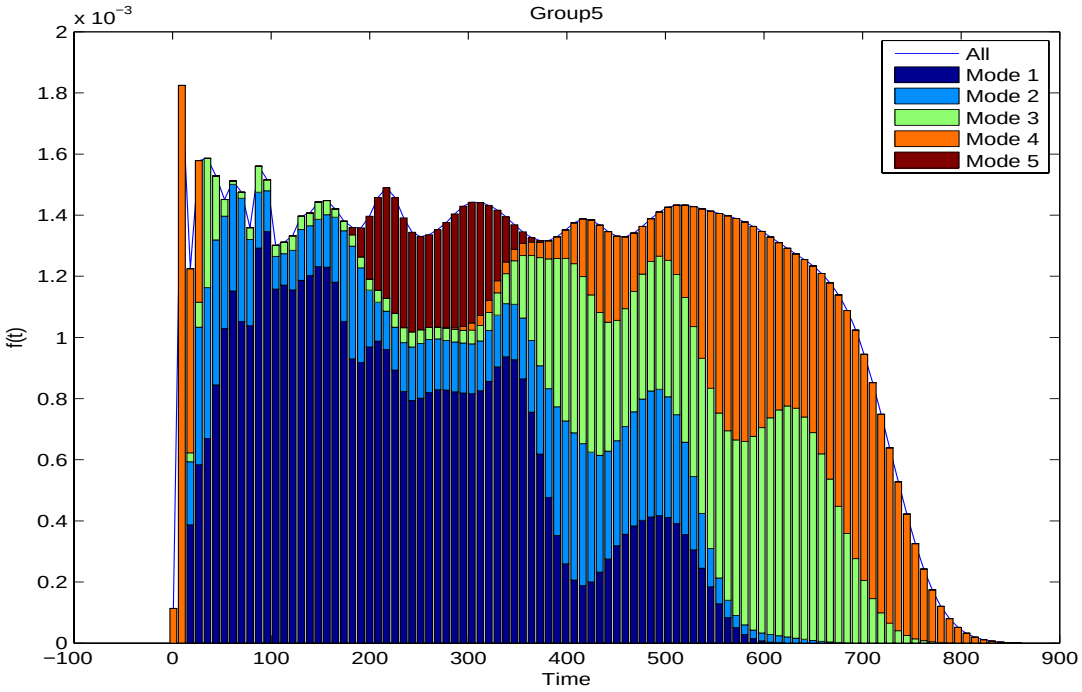
"Provided we have people's permission, we can upload the data, and medical researchers can see who met whom within the set of volunteers, without there being any missing encounters.

FluPhone

- Scan Bluetooth devices every 2 minutes
- Ask symptoms

Analyse Network Structure and Model

- Network structure of social systems to model dynamics
- Parameterise with interaction patterns, modularity, and details of time-dependent activity
  - Modularity
  - Centrality
  - Community
  - Interaction patterns
  - ...

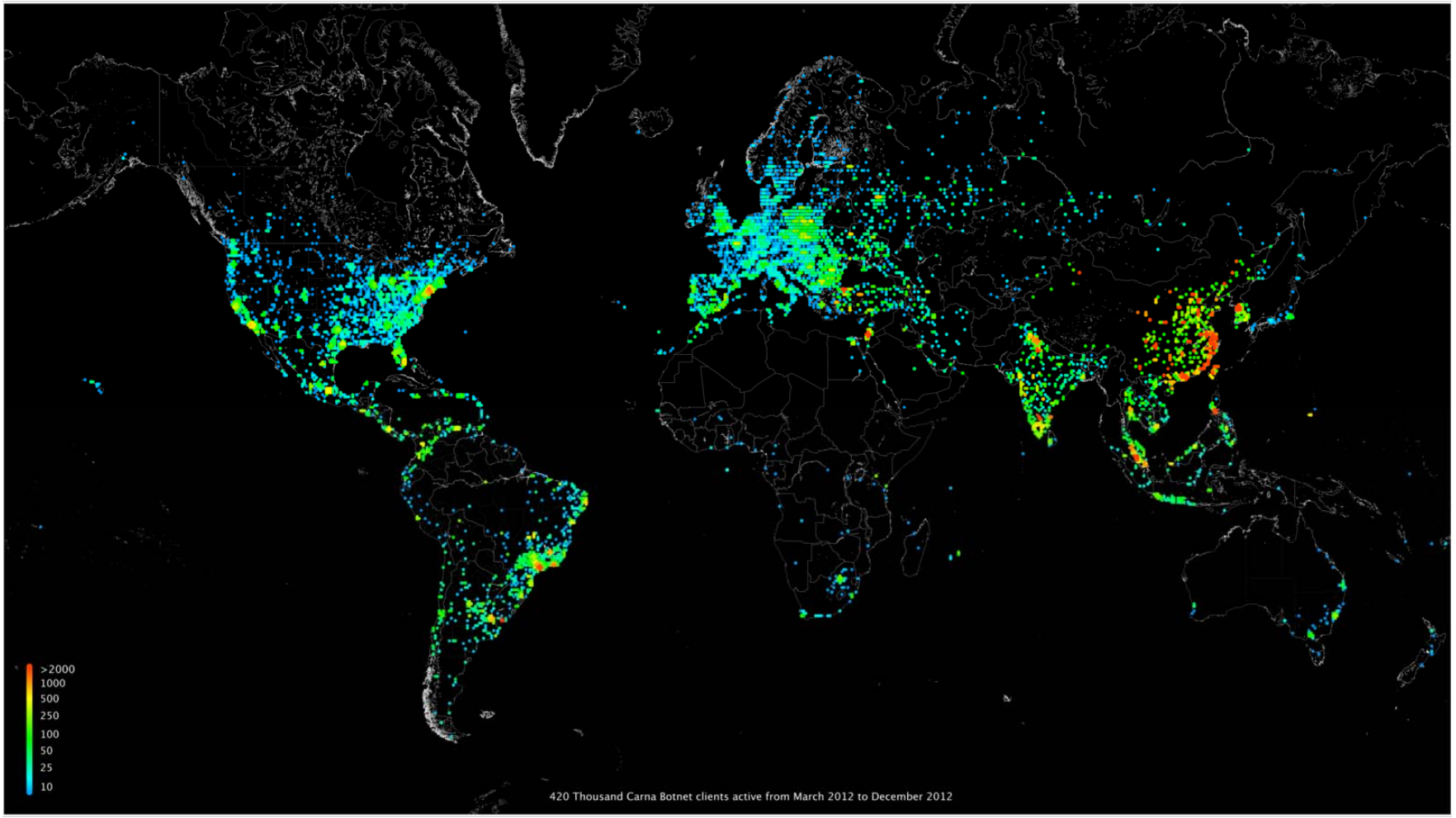


Distribution of times by mode

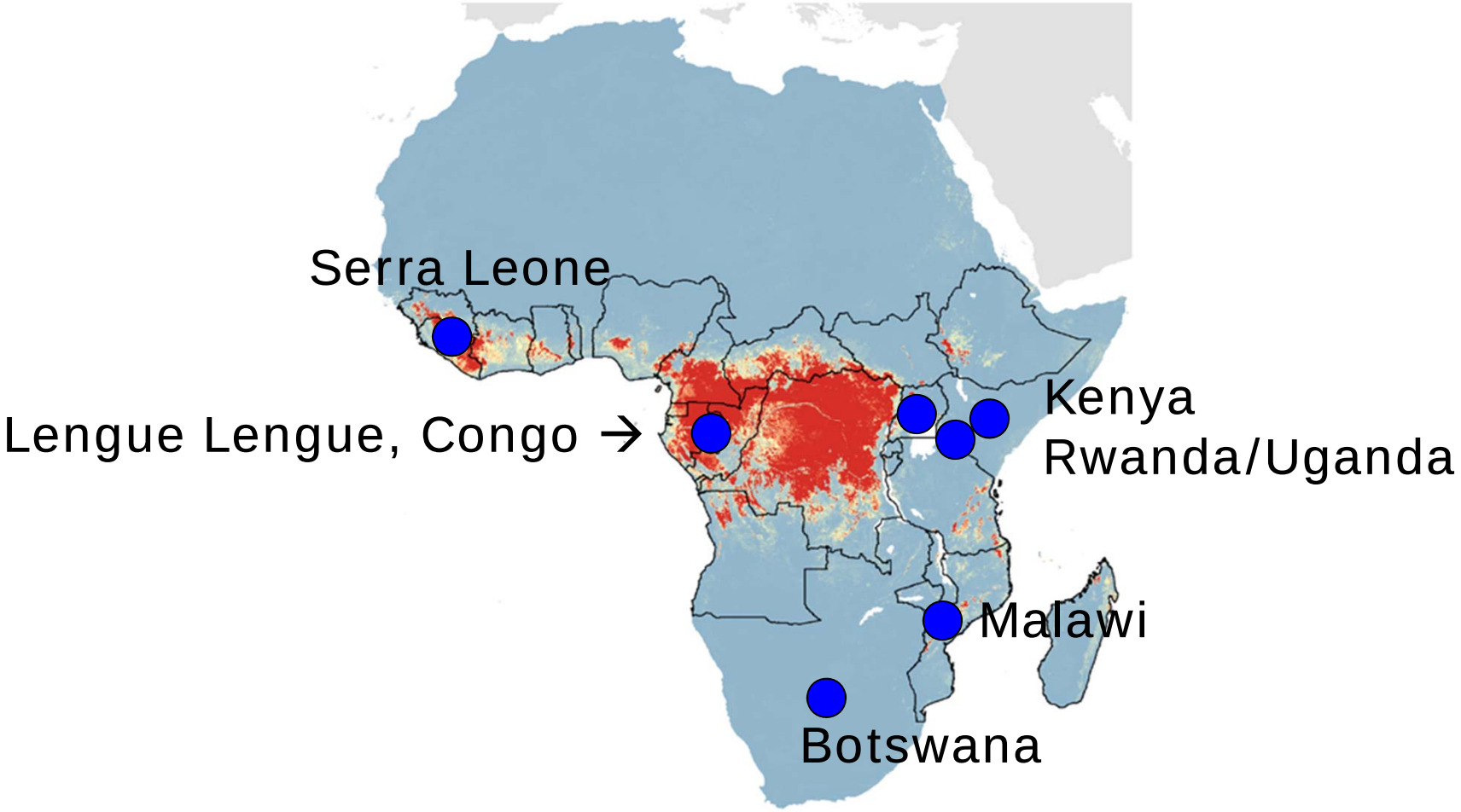
Desirable Epidemiology Study Plan

- University of Cambridge Nurseries
  - Schools – Together with RasPi School Tutorials
- Data Collection in Developing Countries
  - Possible study in Africa
  - Measles, tuberculosis, meningococcal, respiratory syncytial virus and influenza
  - Support various proximity sensing techniques
    - Collect medical symptoms
    - Capture surrounding context (e.g. temperature, light, humidity, GPS-location)
  - Combine diary and interview Survey
  - Need to be repeated data collection
- Input for effective vaccination strategies within limited budget in developing countries

Internet Map in the World – Africa?

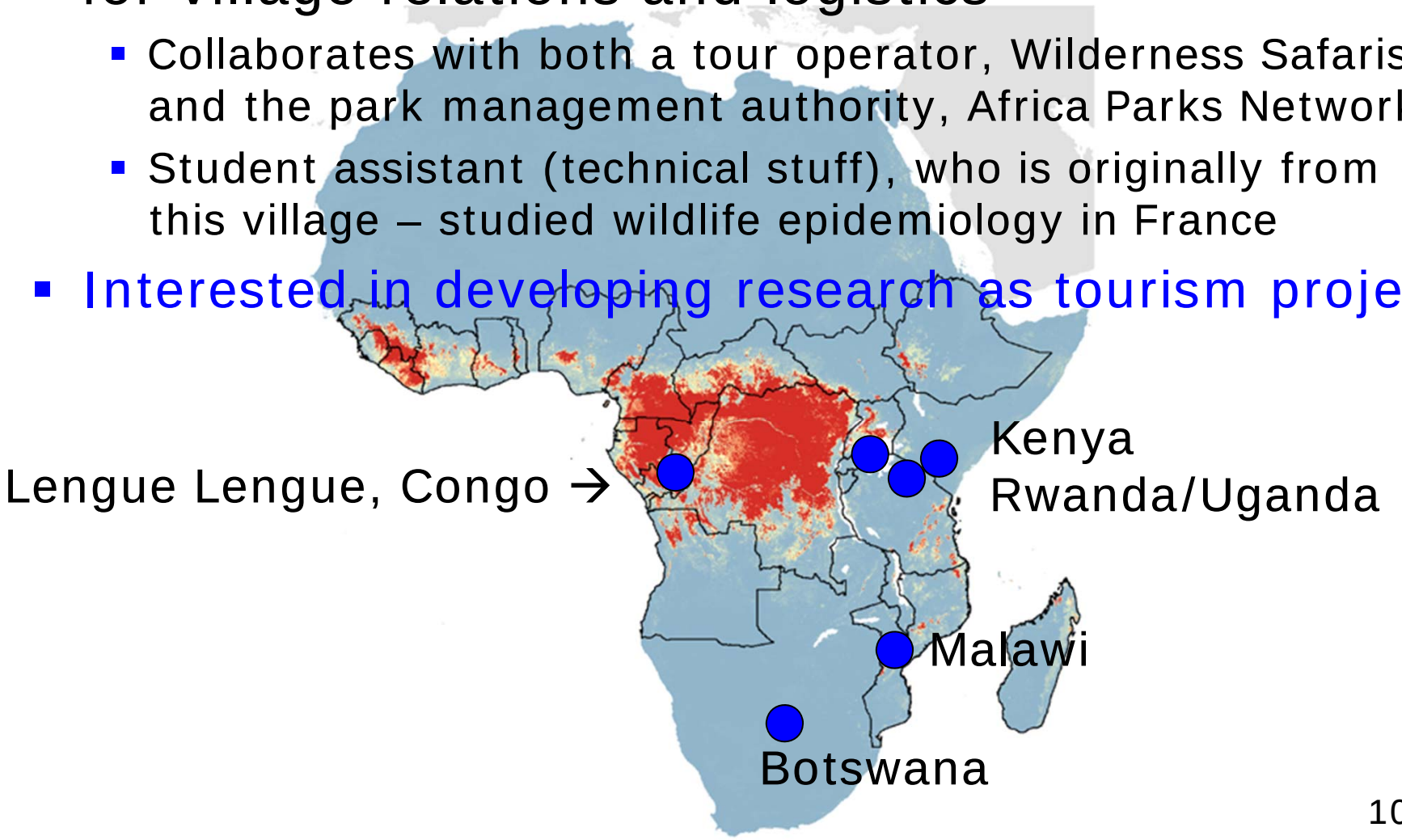


In Africa, Several Planning but …



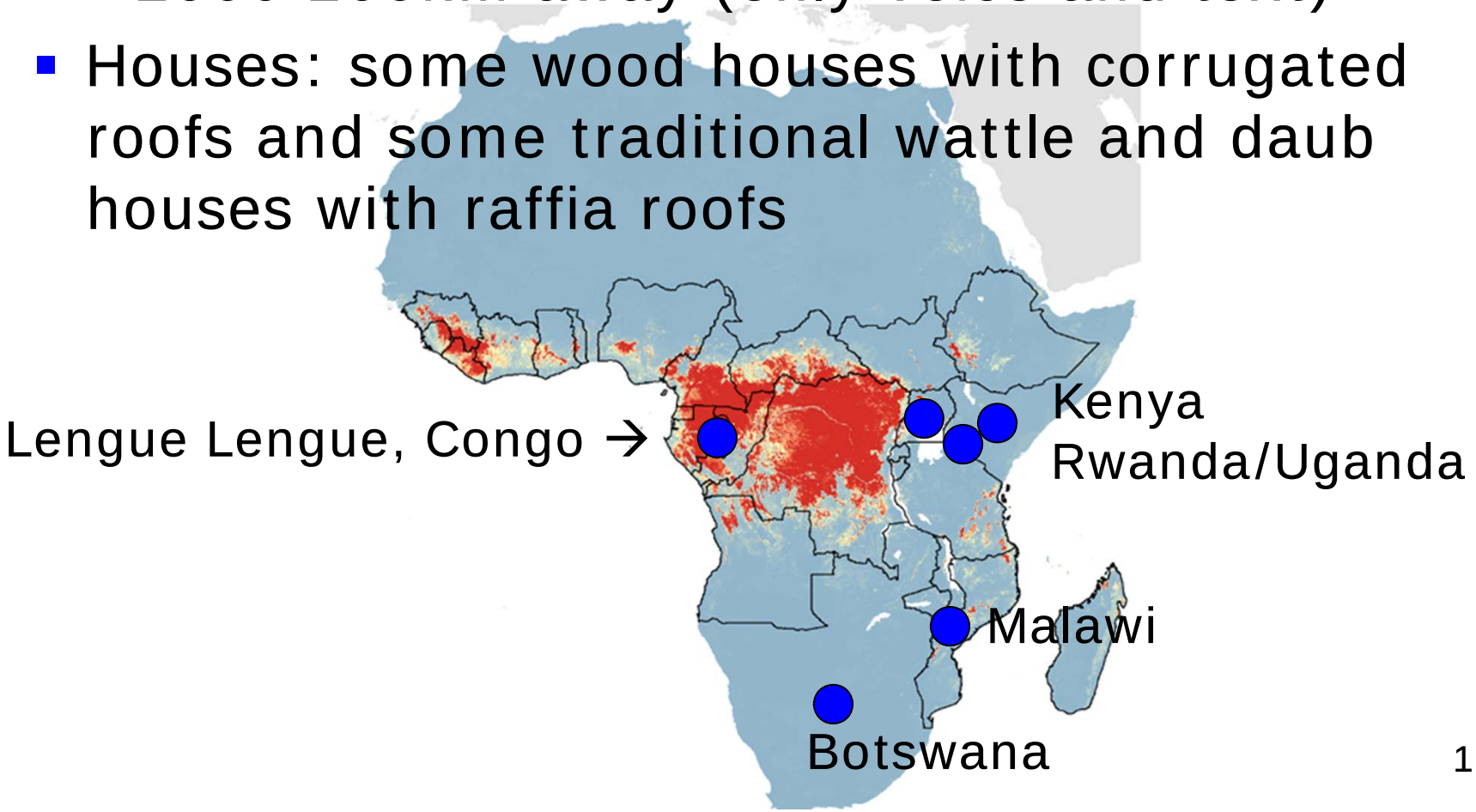
Lengue Lengue, Congo

- Western researcher trusted by people in village for village relations and logistics
  - Collaborates with both a tour operator, Wilderness Safaris, and the park management authority, Africa Parks Network
  - Student assistant (technical stuff), who is originally from this village – studied wildlife epidemiology in France
- Interested in developing research as tourism project



Lengue Lengue, Congo

- Village of about 100 people with no power
- Access to cell phone network from town of ~2000 200km away (only voice and text)
- Houses: some wood houses with corrugated roofs and some traditional wattle and daub houses with raffia roofs



Sensing Platform in Remote Region

- Build a platform for sensing and collecting data in developing countries
  - e.g. OpenBeacon Active RFID tags based contact network data collection
  - Build a standalone network for data collection and communication using Raspberry Pi → RasPiNET
  - Inexpensive network setting
  - Support streaming model
- Education of Raspberry Pi or something technology related…

Tourism Support

- Develop Research Project as a Tourism Support
  - Messaging service within Village + to/from home country
  - Visualisation of experiments
  - Use of directional antenna for P2P WiFi or Bluetooth in the village that can demonstrate messaging service or chat between the different locations within the village without Internet access plus satellite based connection to home
  - Bulk messages gathered by RasPiNET can be transmitted to Internet once a day if the bulk data in USB stick can be carried by the car daily base to the town where the Internet access exists (e.g. 200km away)

OpenBeacon RFID Tags

- OpenBeacon Active RFID Tags
- Bluetooth has an omnidirectional range of ~10m
- OpenBeacon active RFID tags: Range ~1.5m and only detect other tags are in front of them
- Low Cost ~=10GBP
- Face-to-Face detection
- Temporal resolution 5-20 seconds
- On-board storage (up to ~4 logs)
- Batter duration ~2-3 weeks

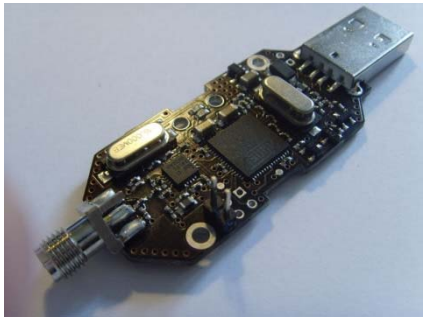
An OpenBeacon RFID tag

OpenBeacon Ethernet EasyReader

Raspberry Pi based Reader

- OpenBeacon Ethernet Readers need Ethernet connection (Cannot be deployed outside)

→ Using USB based reader with Raspberry Pi

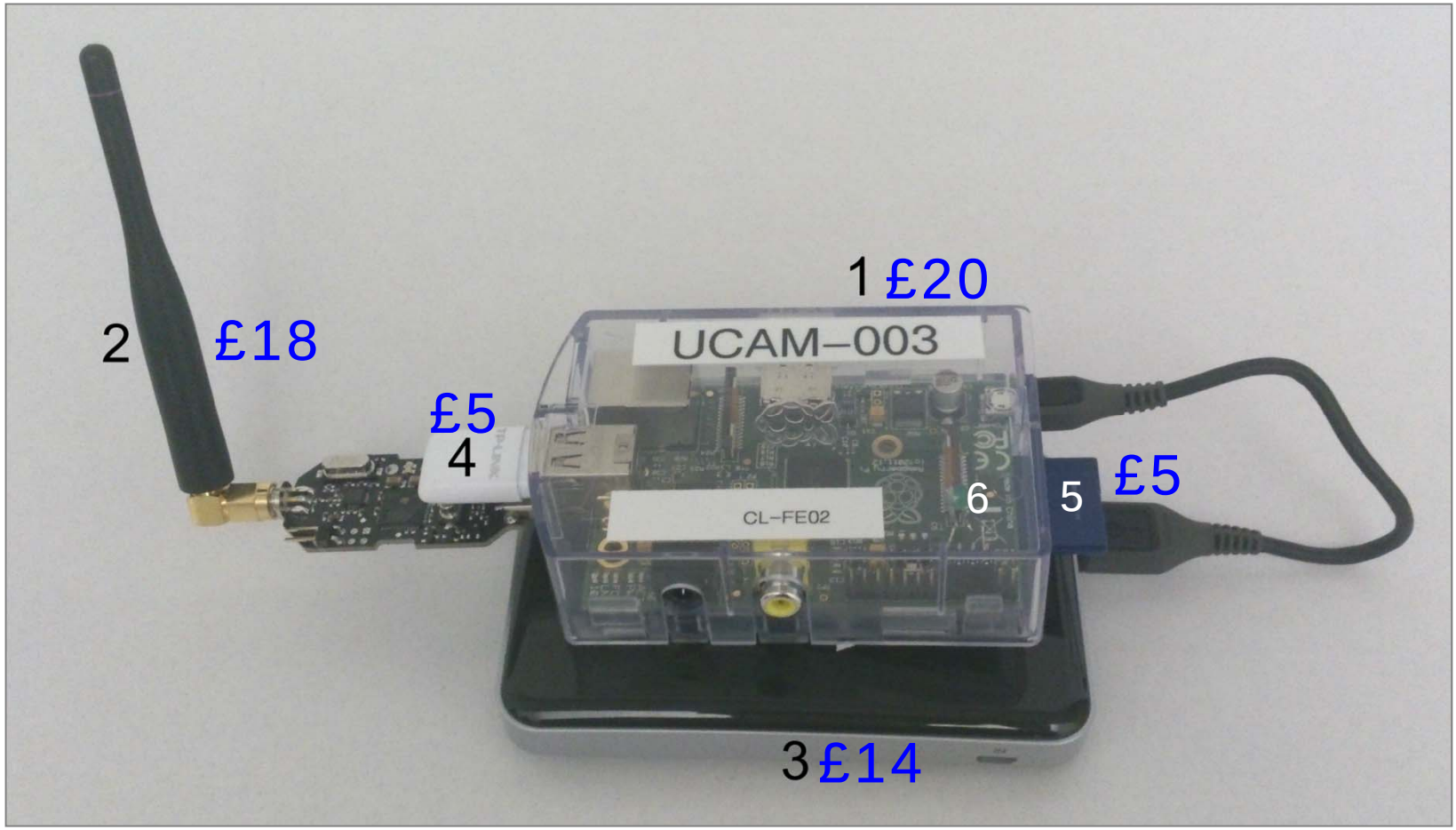


OpenBeacon USB Reader

- USB reader + Raspberry Pi
  - Raspberry Pi (700MHz ARM11 CPU, 512MB RAM, 2 USB ports, SD card port, Ethernet port)
  - WiFi connectivity
  - Mobility (w/ battery pack)
  - Work without a server – SD card storage

TP-Link TL-WN723N
Wifi Dongle

Raspberry Pi OpenBeacon Reader



1. Raspberry Pi
2. OpenBeacon USB reader
3. Battery Pack (7000mAh)
4. WiFi dongle
5. SD Card
6. LED

Raspberry Pi based Sensing Platform

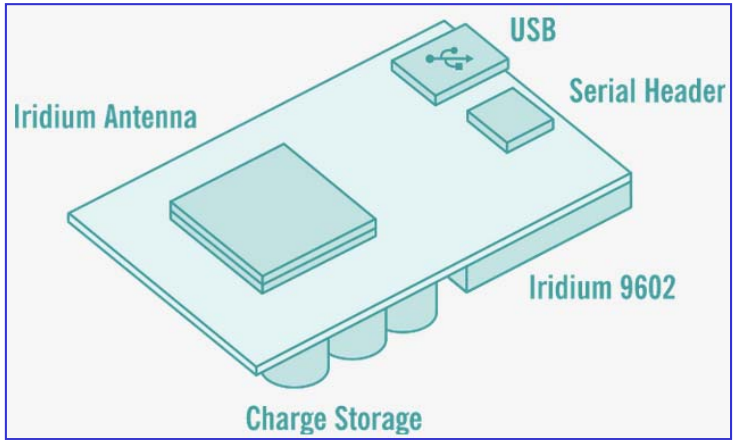
Data can be stored in SD card, transmitted to Data Mule node, or use of WiFi AdHoc mode transmission to Gateway

Configuration: WiFi AdHoc, Software Access Point, WiFi Direct, DTN Data mule

Single/Multiple Satellite Gateway nodes

Satellite Communication

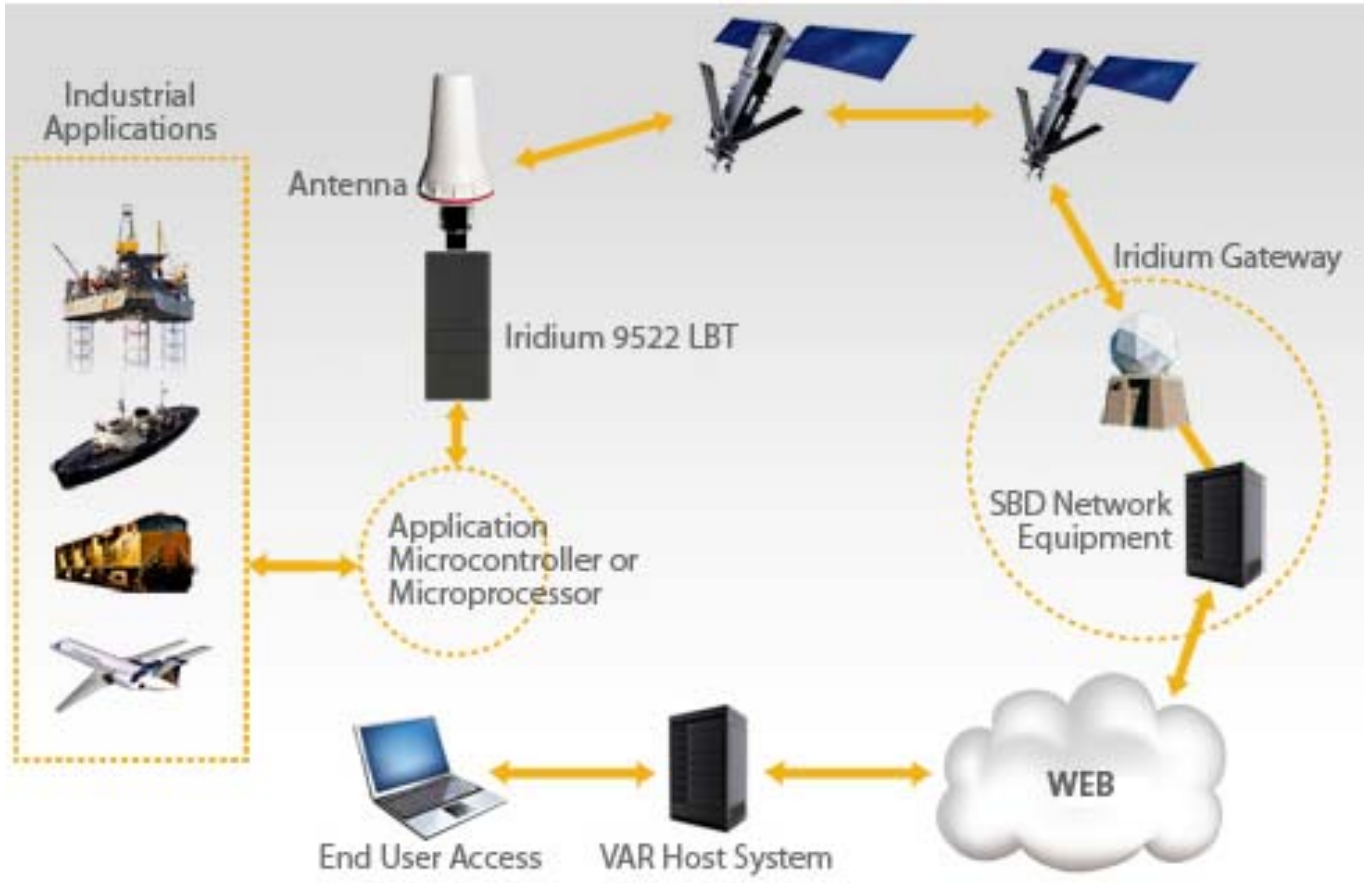
- Satellite module integration in Raspberry Pi
  - RockBLOCK Satellite Module (~=£120)
  - Uses Iridium Satellite Network: Short Burst Data(SBD)
  - Iridium SBD session roughly every 10 seconds
  - To email address, or own web service (i.e. HTTP POST)
  - pay-as-you-go – 34 bytes per message (Hex encoded)
    - 50 credits - 12p/message
    - 20000 Credits – 4p/message



RockBLOCK satellite module

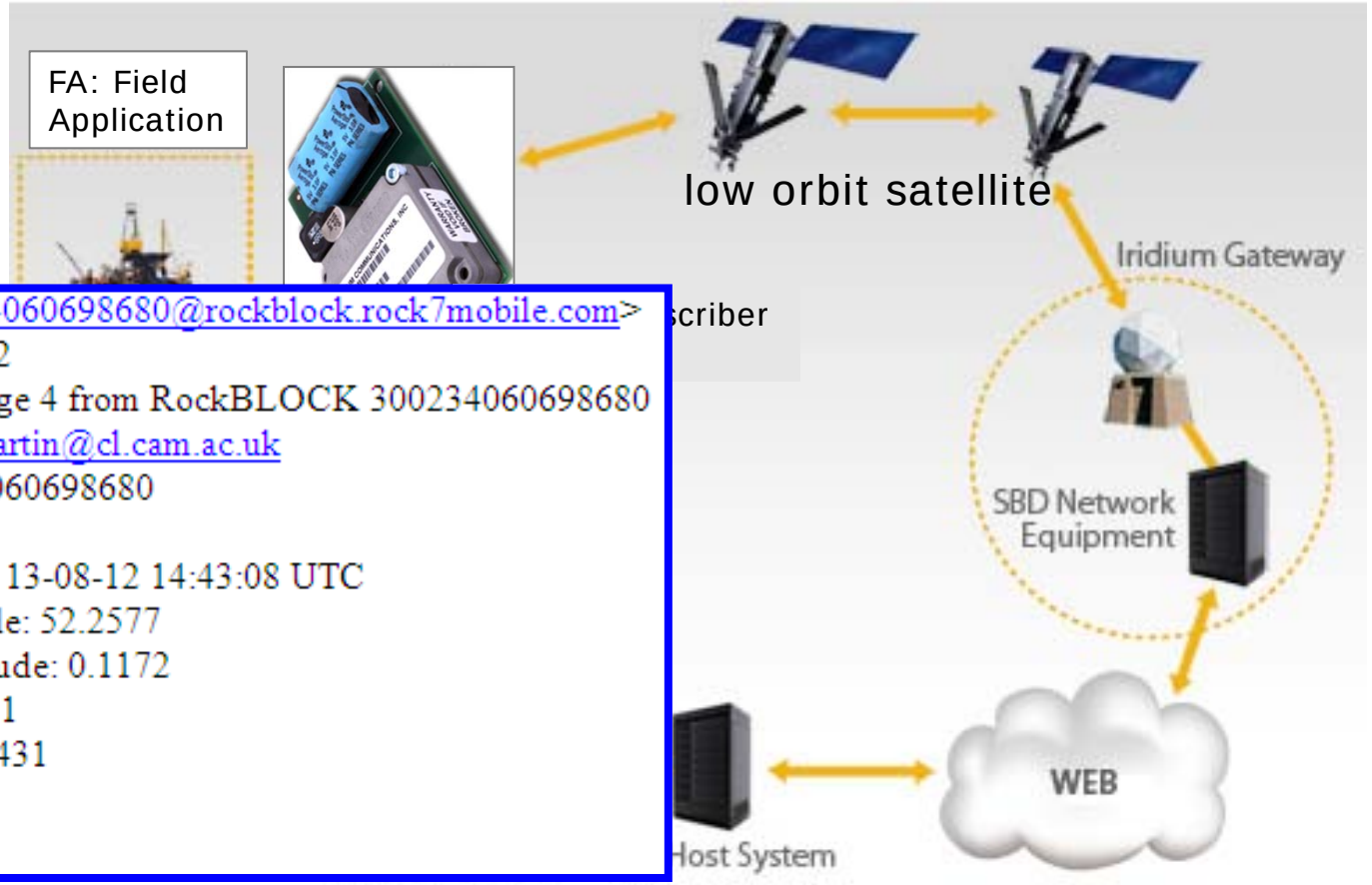
RasPiNET with Satellite Communication

- Satellite module is integrated
- Useful in developing country



Iridium SBD

- Interface between FA and ISU is a serial connection with extended proprietary AT commands
- Interface is used to load/retrieve messages



From: <300234060698680@rockblock.rock7mobile.com>
Date: 2013/8/12
Subject: Message 4 from RockBLOCK 300234060698680
To: abraham.martin@cl.cam.ac.uk
IMEI: 300234060698680
MOMSN: 4
Transmit Time: 13-08-12 14:43:08 UTC
Iridium Latitude: 52.2577
Iridium Longitude: 0.1172
Iridium CEP: 11
Data: 7465737431
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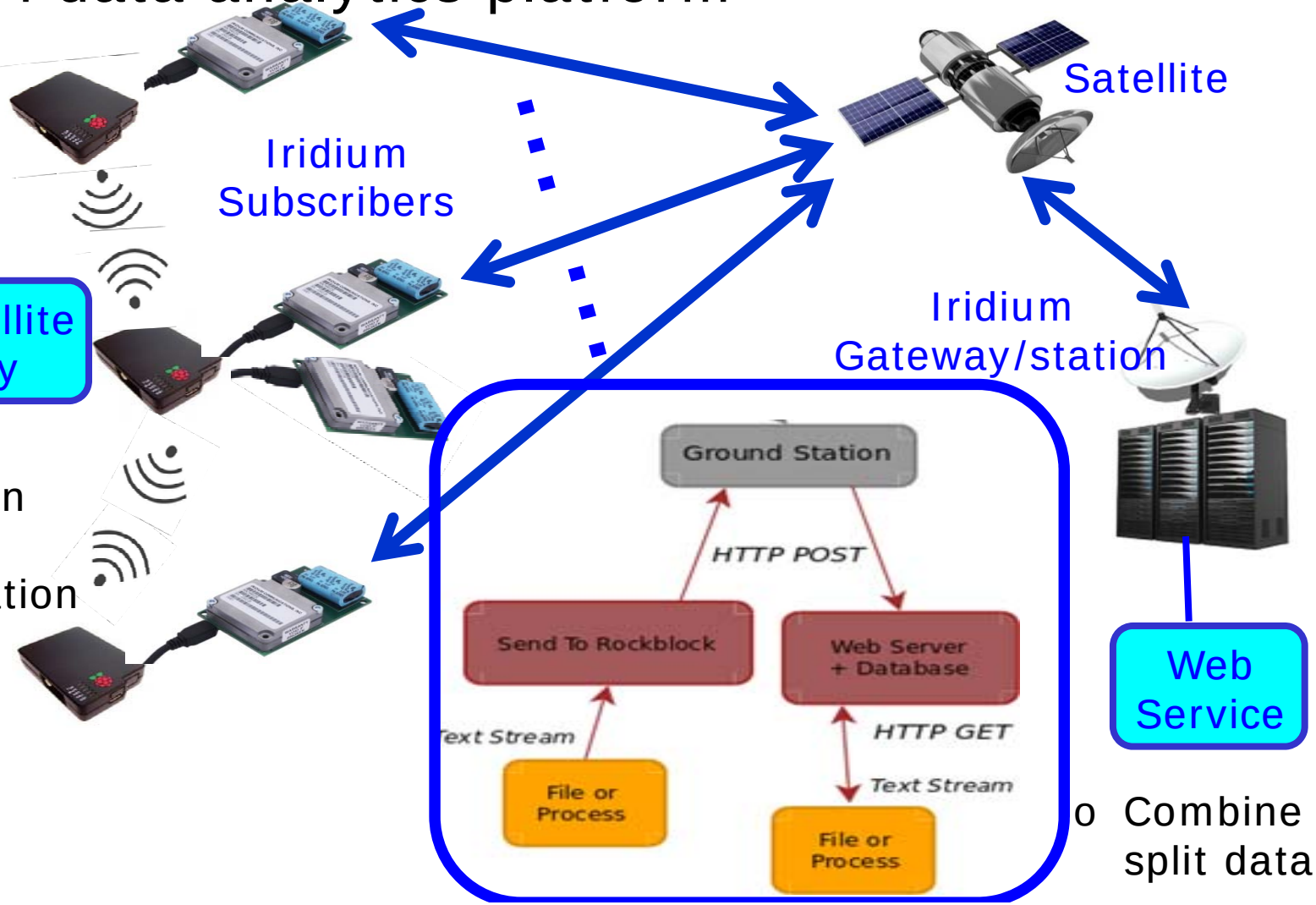
test1

RasPi Satellite Gateway

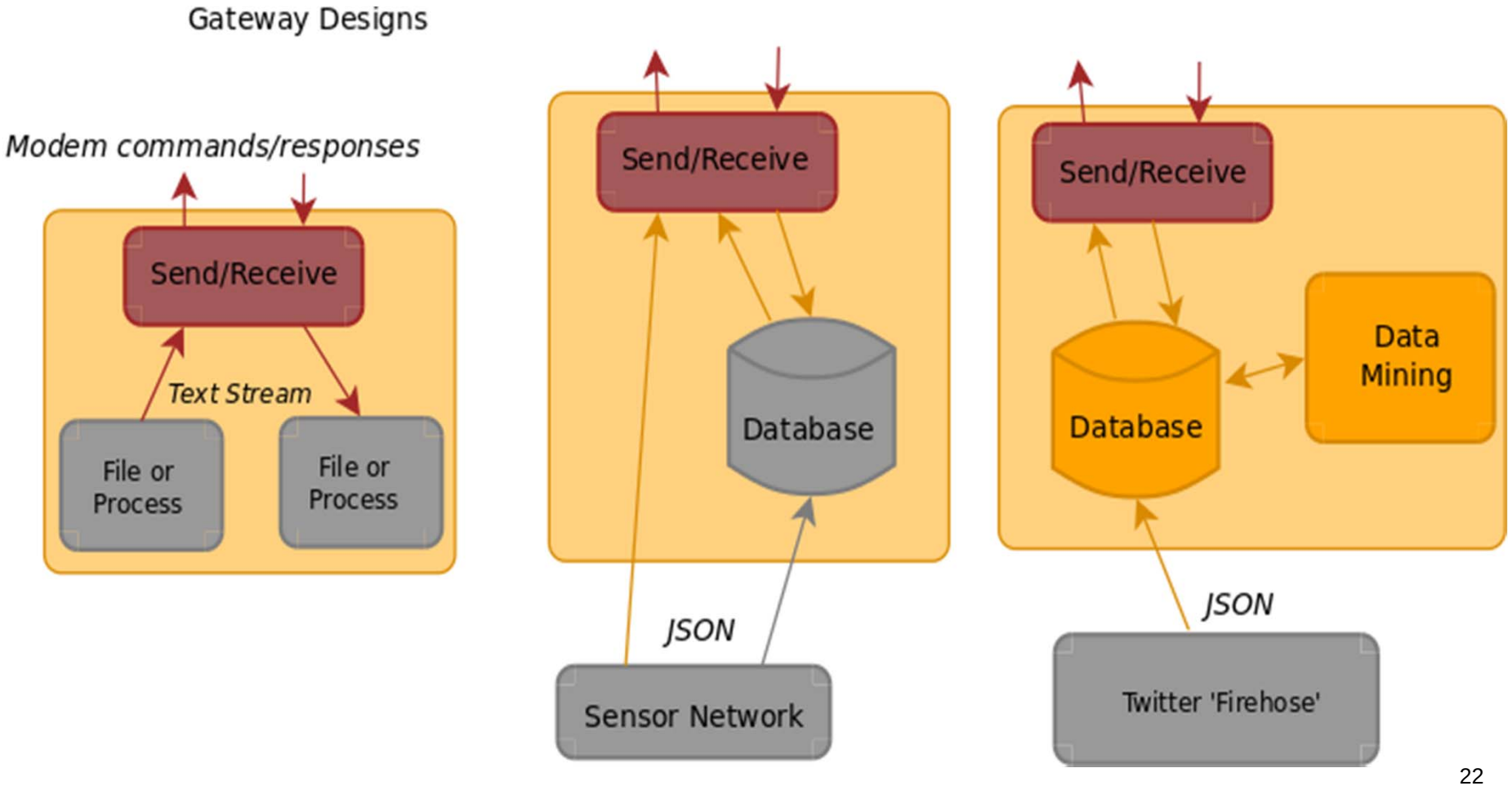
- Build stream processing paradigm
- RasPi data analytics platform



- Data filter, aggregation
- Analysis
- Fragmentation
- Multicast support
- Combine split data

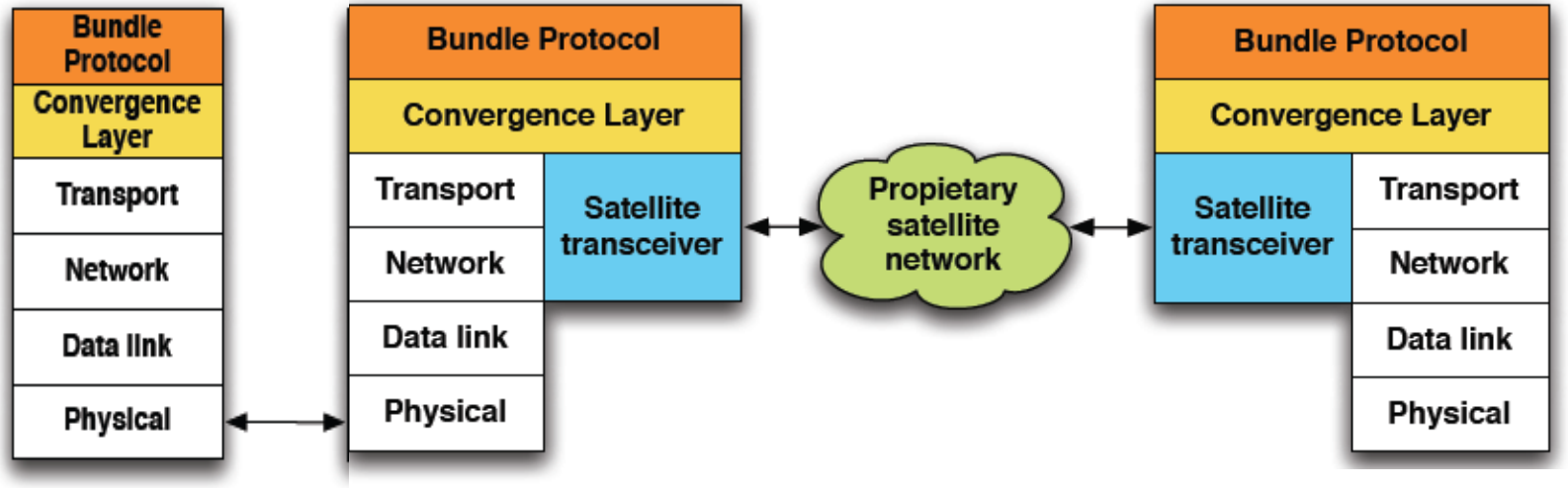
Extension to JSON Interface

- Text and JSON (converted from RFID/Twitter..)

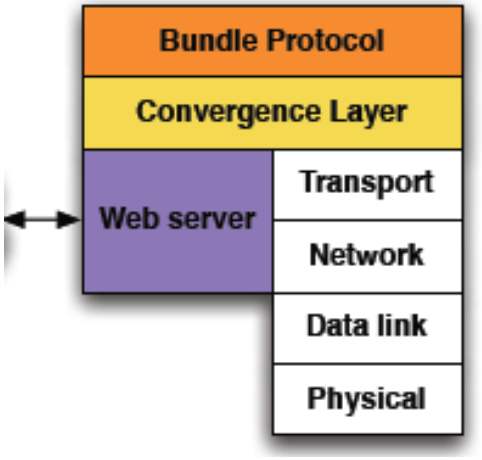


Communication Protocol

- Protocol for communication between devices with satellite transceiver



- Rockblock provides Web Service Interface
- also Email Interface



Data Compression

- Message to Iridium network < 340 bytes
- Received message < 270 bytes every 10 seconds
- Currently DTN2 also ION
- Additional compression and fragmentation protocols are needed that are not included in the default stack of communication

- Raspberry Pi has ability of data processing
  - Cluster of Raspberry Pis for MapReduce
  - Data analysis within Raspberry Pi

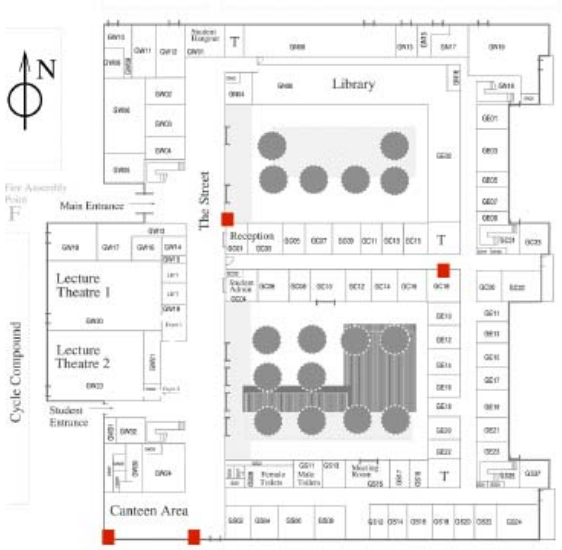
Pilot Study in Computer Laboratory

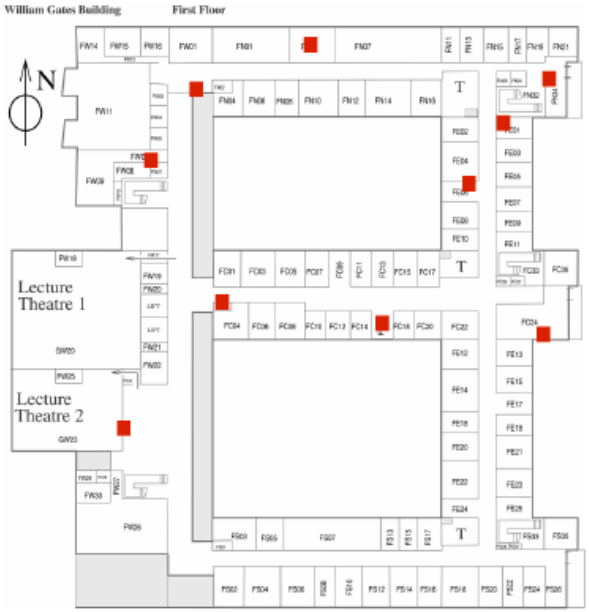
- 15 RasPi OpenBeacon Readers around Computer Laboratory
- 30 participants (4 groups)
- 3 days of data collection

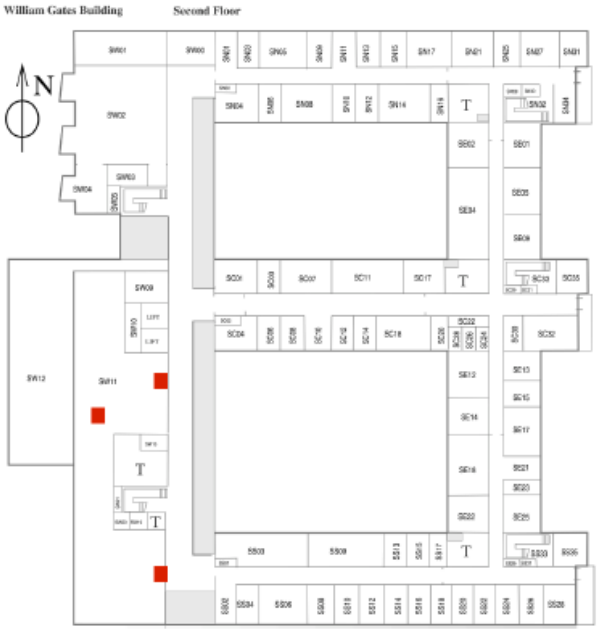
A participant wearing three RFID tags

Setting RasPiNET on 3 Floors

- Use of Data Mule approach for Data Collection
- Satellite Communication for sending statistics and changing sensing rate

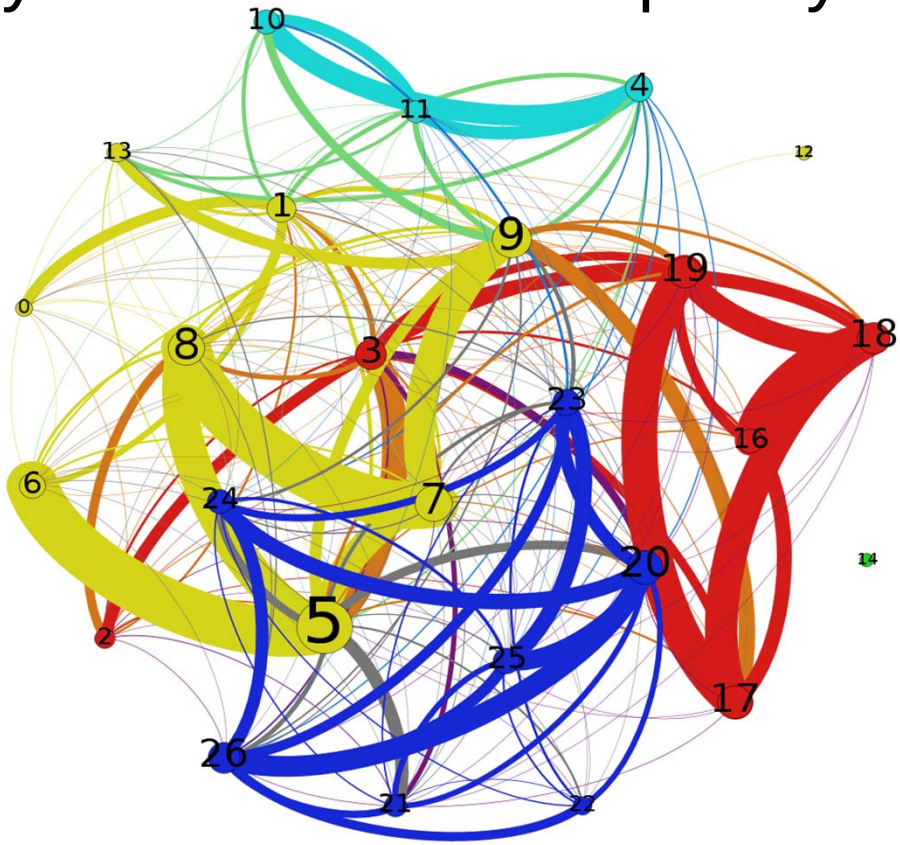






Post Data Analysis on Pilot Study

- Community Detection (4 groups and bridging nodes can be identified)
- No in-depth traffic analysis or network capacity evaluation yet
- One simulator based Simulator (w and w/o satellite connectivity)



Let's make Data Collection in Africa happen!

RasPiNET: Decentralised Network for Data Collection and Communication with Raspberry Pi

- Ready to Deploy Inexpensive Decentralised DTN Networks
- Remote Sensing and Data Collection Platform
- Standalone Distributed Computing Platform

- Different board (e.g. ARM) → VM

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