Delay Tolerant Networking for Sensor Networks

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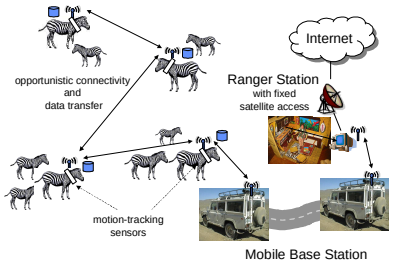
Sensor Networking Challenges

- **Network Infrastructure**
  - Sensor gateways may be intermittently connected to operator's network
  - Lack of existing infrastructure may prevent long term deployment of sensor networks, because it may be too risky, difficult, or expensive to install
  - If sensors generate data more frequently than connectivity becomes available, data must be buffered in-network to avoid loss
- **Interruption**
  - Links may be interrupted due to scheduled down time, interference, or environmental hostility
  - Due to scarcity of power, cost of communication can be high, making efficient utilization of communication opportunities very important
- **Heterogeneity**
  - Challenged networks cannot be assumed to be running a common set of protocols in each node
  - These networks need to accommodate a high degree of variation in naming, addressing, rate control, and routing approaches
  - Therefore, support for proxies that can be placed at points of interconnection is of significant importance

ZebraNet

- **Goal: Track mobility patterns of zebras in Kenya**
- **Infrastructure:**
  - Custom tracking collars for selected zebras form a peer-to-peer network
  - Mobile base station collects data from collars when researchers are in the field
- **Challenges:**
  - Network connectivity is intermittent and opportunistic
  - Base station may not be present when data is collected and distributed
  - Connectivity between base station and Internet is not maintained in the field
- **DTN Solutions:**
  - DTN routing accounts for opportunistic connectivity and lack of end-to-end paths
  - Network storage allows DTN nodes (the collars, and the base station) to buffer data bundles until connections are available
  - Integrated network architecture allows automated transfer of pending bundles once connections are re-established
- **Result: Physical presence of the researchers is no longer required at the deployment site in order to collect and publish zebra mobility pattern data**



The Zebranet sensors have eventual connectivity with the Internet via several mobile and stationary intermediaries.

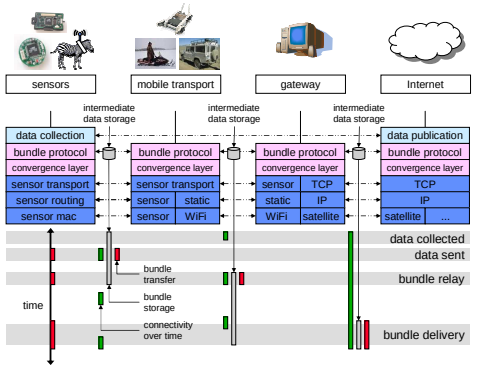
DTN Architecture

- **Asynchronous, store-and-forward message delivery** permits communication even without contemporaneous end-to-end connectivity
  - Mobile store-and-forward **data mules** can *physically* transport data from hard to reach sensors to a stationary gateway with Internet access
  - DTN nodes can buffer data bundles until the arrival of the data mule, during scheduled down time, and during periods of network disruption resulting from interference.
- Built in support for **fragmentation** and **delay tolerant routing** provides better utilization of resources in the face of interruptions
  - The DTN architecture supports a sophisticated approach to routing that incorporates store-and-forward. Algorithms include strategies for **probabilistic, scheduled, and opportunistic connectivity**. Use of **multi-path** routing makes more efficient use of available communication resources
  - In **proactive fragmentation** if communication is scheduled, messages can be split to fit contact opportunities ahead of time
  - **Reactive fragmentation** handles interruptions by repackaging the data successfully transferred, and the data remaining to be transferred so they can be delivered as independent bundle fragments
- **Convergence layer protocols** provide adaptation among underlying protocols for heterogeneous networks
  - Standardized way to adapt existing protocols (such TCP, UDP, or sensor network protocols) to be used as underlay protocols for hop-by-hop DTN message delivery
  - Convergence layers add functionality to support reliability of DTN messages, and handle signaling for fragmentation and connection re-establishment
- DTN's **flexible naming scheme** can embed names/address from other protocols, and provides **late binding** capability
  - Uses a **tuple** that consists of a globally unique *region identifier*, and a region-specific *administrative identifier*
  - The *administrative identifier* is only resolved inside the destination region, thereby providing **late binding**

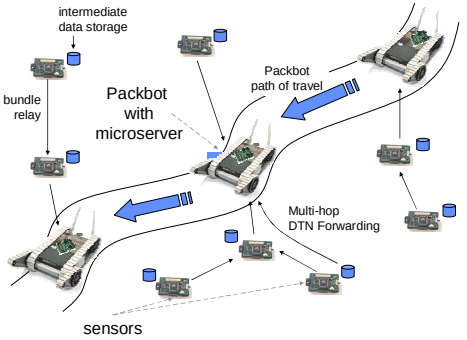
Ad Hoc Seismic Array

- **Goal: Collect data from widely distributed sensors**
  - 50-100 nodes, each 5-10km apart
  - Stretching 500 km through Mexico
- **Infrastructure:**
  - Packbot, an unmanned ground vehicle (UGV) developed by the US military, transporting a sensor and a microserver
  - Widely distributed sensor forming multihop paths to the Packbot's path of travel
  - Stationary gateway
- **Challenges:**
  - Lack of infrastructure and sheer distance between sensors prevents end-to-end connectivity
  - Sensor nodes must dynamically route data to the node nearest to the Packbot path even in its absence
- **DTN Solutions:**
  - Asynchronous, store-and-forward message delivery supports multi-hop delivery of data, and allows use of Packbot as a *data mule*
  - Routing accounts for buffer management, which allows selection of best next hop based on buffer availability and proximity to to the Packbot path
- **Result: Use of a mobile *data mule* permits efficient deployment of sensors over a large deployment area**

The Delay Tolerant Networking Architecture



Transmission of data from a sensor node to a destination application on the Internet using DTN. Since there is no contemporaneous path between the sensors and the Internet, the DTN bundle protocol stores the bundles until the next available connection arrives, allowing *eventual* delivery of the sensor data to its destination.



The Packbot travels through the sensors, using the DTN infrastructure to collect the data.

Delay Tolerant Network Research Group

http://www.dtnrg.org