Design Principles for Opportunistic Communication in Constrained Computing Environments*

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* Invited paper

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Outline

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Take home points

- Capacity of opportunistic communication systems is dependent on our ability to maximize communication during opportunistic connections.
- Developing in low cost, low power constrained computing environments has unique design challenges.
- Lessons learned: design principles for opportunistic communication.

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Motivating opportunistic communication systems

- Recent rapid explosion of cell/smartphones and other embedded wireless devices
  - Recycled cell phones are abundant and affordable (1.15 billion in 2007)
  - Smartphone are projected to soon outsell laptops
  - Primary communication mechanism in developing regions
- Devices with multiple radio interfaces
  - Constantly connected over long range interfaces (cellular)
  - Intermittent connectivity over short range interfaces (Wi-Fi, Bluetooth, etc.)
- Devices can be highly mobile
  - Embedded in vehicles
  - Carried by users

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What is wireless opportunistic communication?

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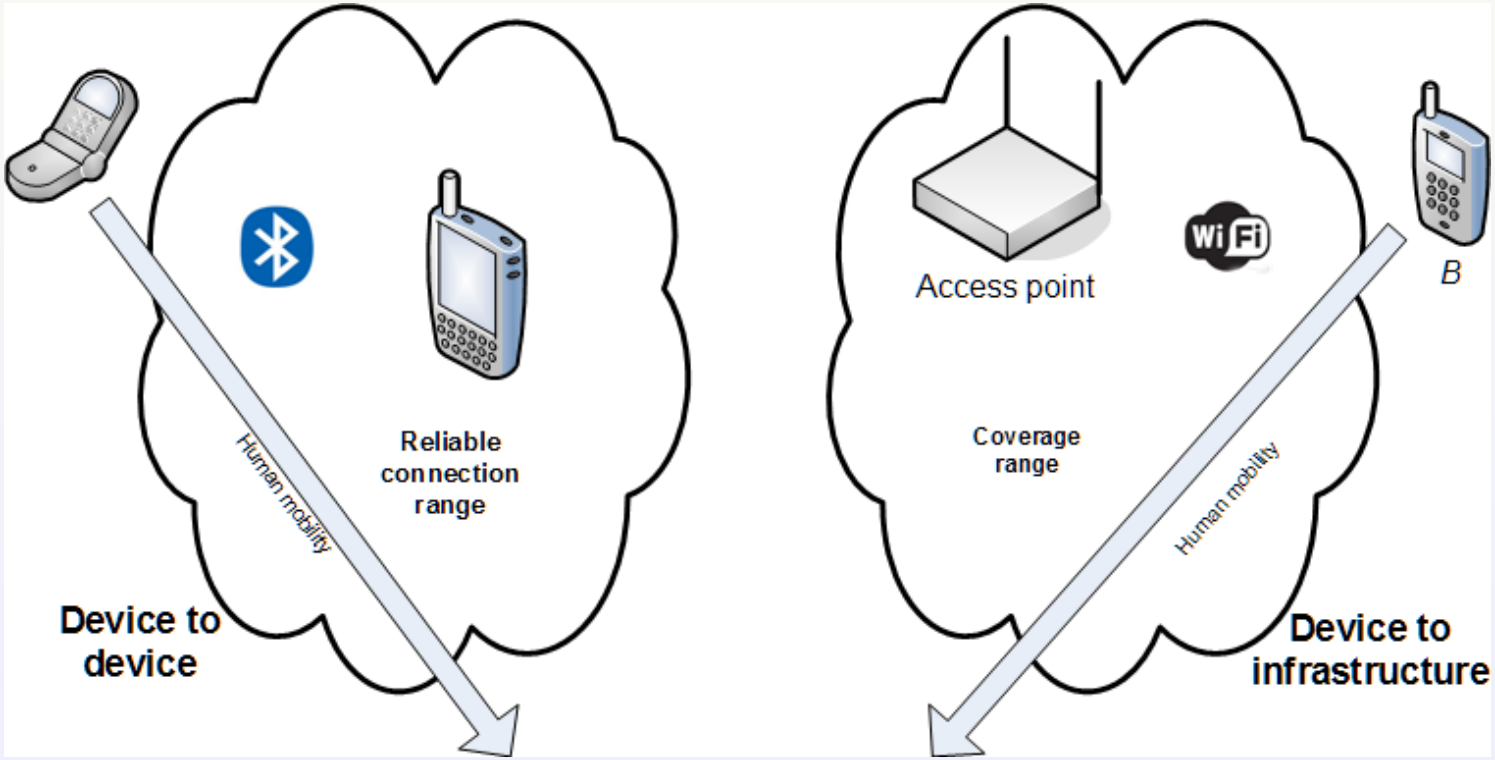
Exploiting intermittent periods of wireless connectivity to exchange data with infrastructure and other devices.



Application that use opportunistic communication

- **Drive-by wireless**
- **Delay tolerant networking**
  - Intermittent connectivity between DTN nodes.
  - Ex. two Zebras come nearby, transfer data.
- **Pocket switched networking**
  - Data disseminated between mobile devices.
- **BlueTorrent and opportunistic Podcasting**
  - Fragments of data are exchanged between pairs of devices.

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Existing systems

We motivate challenges in opportunistic communication by considering two existing system:

- KioskNet
- MobiClique

KioskNet

What is KioskNet?

A mobile system that provides low cost Internet to developing regions.

- Uses buses and cars as **mechanical backhaul** to carry data to and from rural village kiosks and Internet gateways.

How KioskNet works

- Low cost, low power *Kiosk Controller* located in rural village.
- Data created by villagers fragmented into bundles and stored on the Kiosk Controller.
- Bundles transferred to a *Ferry* as it drives through a village.
- Ferries upload/download data to and from Internet *Gateway*.
- Gateway forwards data over the Internet to a *Proxy*.

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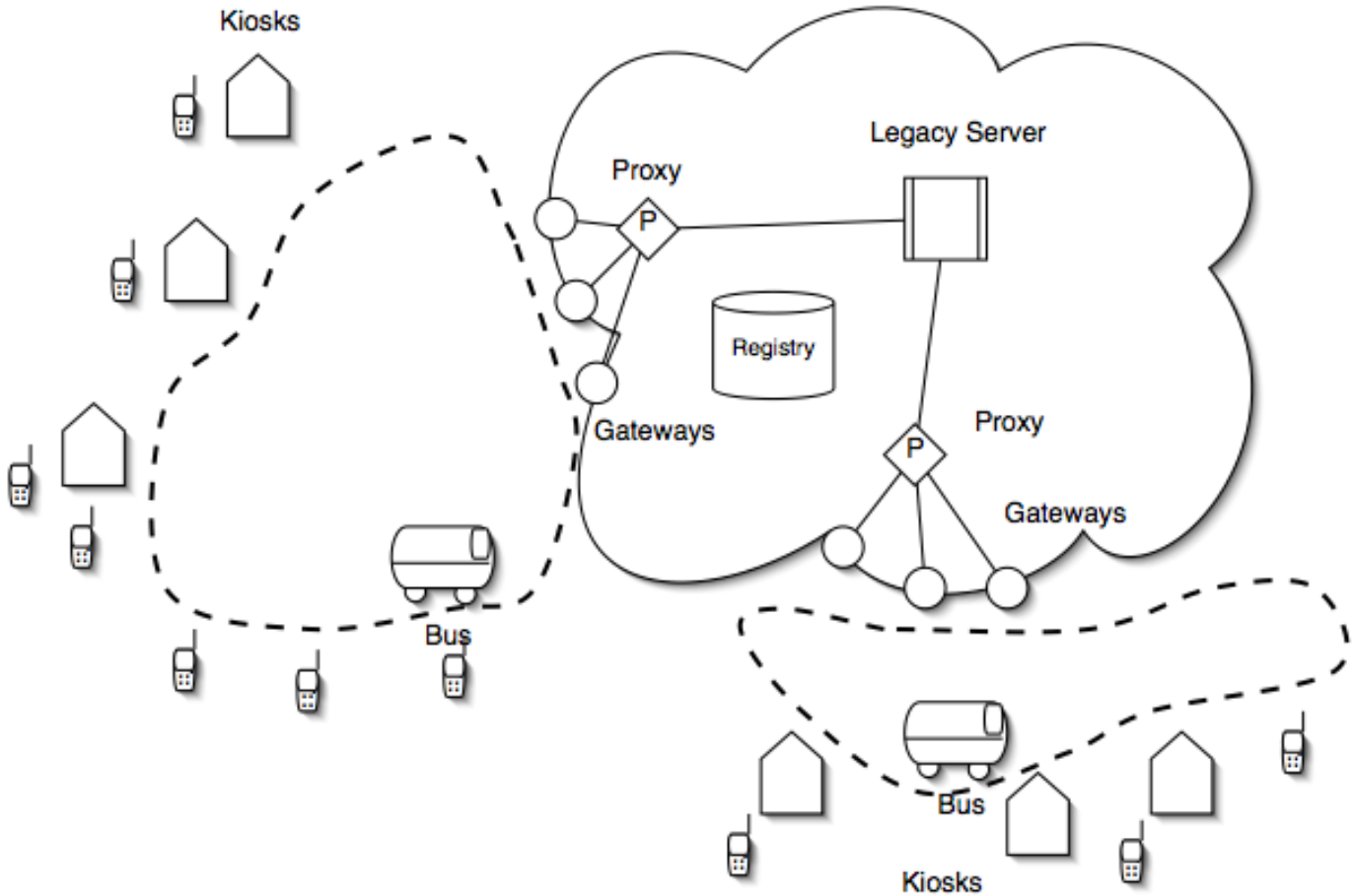
KioskNet Overview



KioskNet village deployment in Anandapuram, India

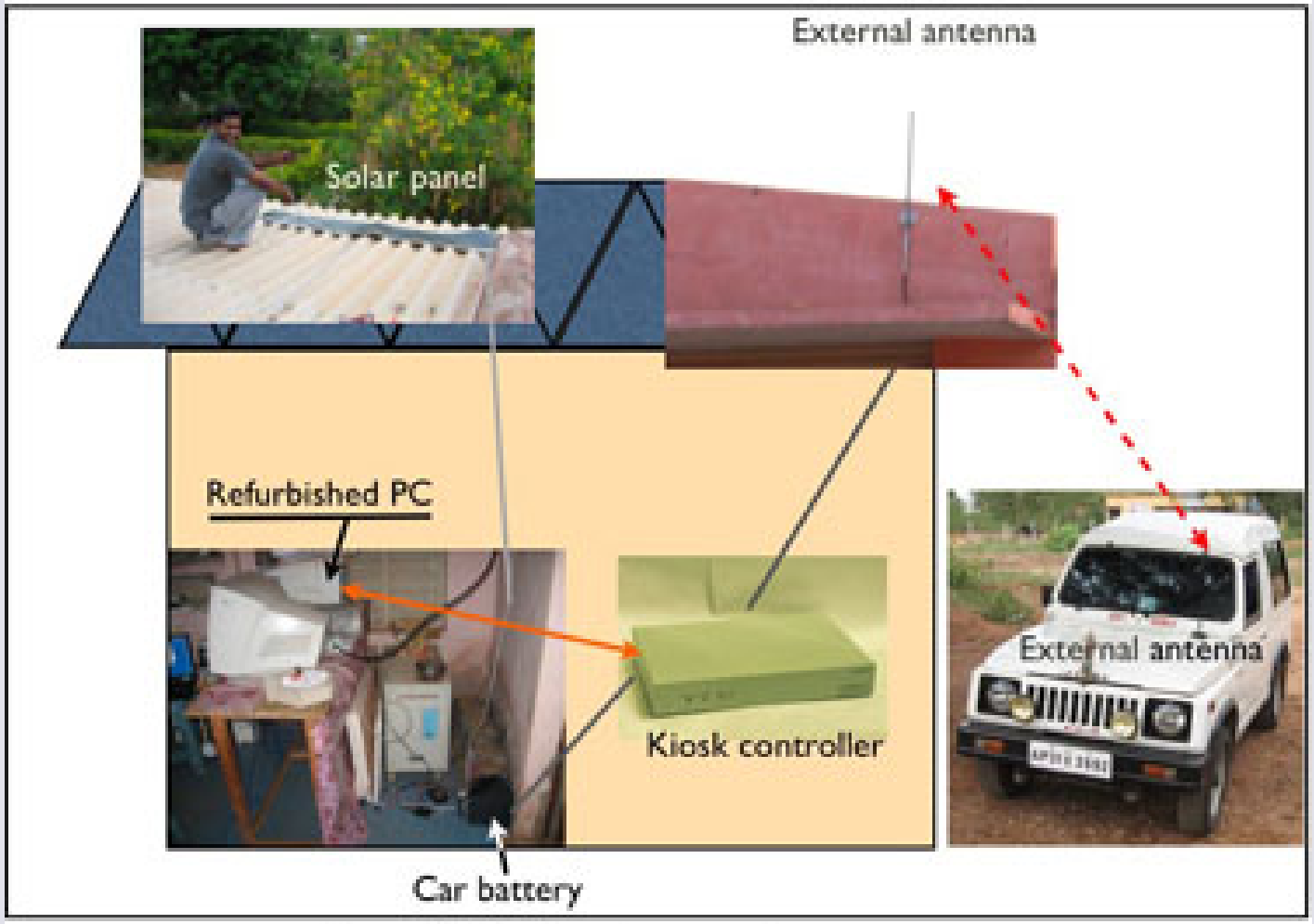


Figure 1: Overview of our system

MobiClique

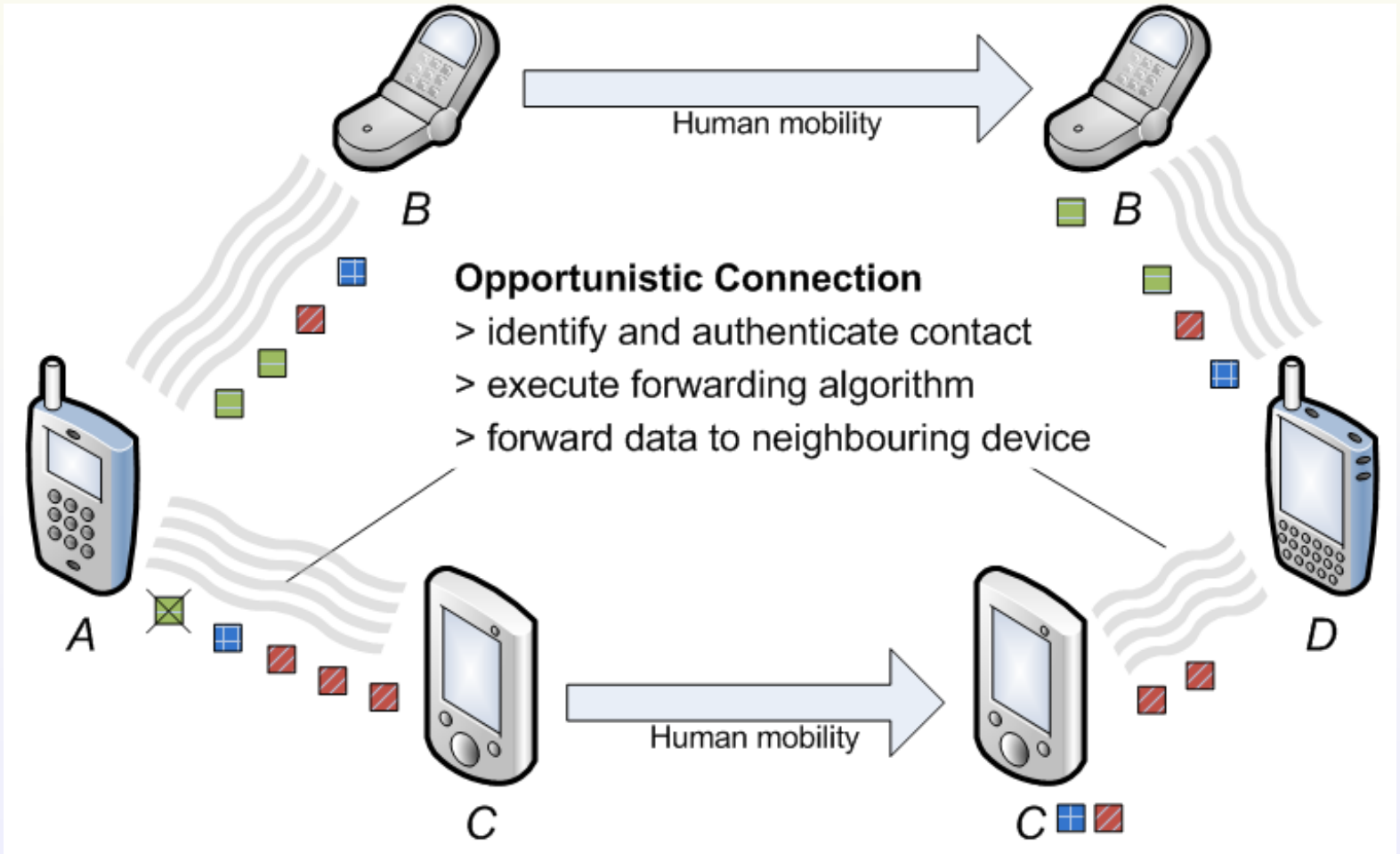
What is MobiClique?

Form of pocket switched network that exploits natural human mobility and opportunistic wireless connections to disseminate data from device to device.

How MobiClique works

- System depends on intermediate devices to ferry data between source and destination.
- Continuous scanning for neighboring devices over Bluetooth.
- On establishing an opportunistic connection, devices exchange authenticating information and metadata.

Mobile devices operating in a pocket switched network



Fundamental constraint

The effectiveness of each system is primarily bound by its ability to transfer data during an opportunistic connection.

To maximize the capacity of each system, we must maximize the quantity of data reliably exchanged during a wireless opportunistic connection.

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Constrained computing environment

- Constrained computing environment poses challenges in opportunistic communication.
  - **Limit energy consumption**
    - Must minimize heat and conserve battery life.
  - **Limited RAM**
    - Frequent page swaps or allocation failures.
  - **Low-power CPU**
    - Inhibits all CPU intensive operations (including wireless network I/O).
  - **Poor and intermittent communication**
    - Packet losses cause backoffs.
  - **Slow persistent storage**
    - Throughput is inhibited by reading from persistent storage.
- Discussion of resource constraints: [Oliver,MobiEval 2007]

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Net
Disk

Phases of an opportunistic connection

Scanning Phase

Continuous scanning of neighboring devices.

Setup Phase

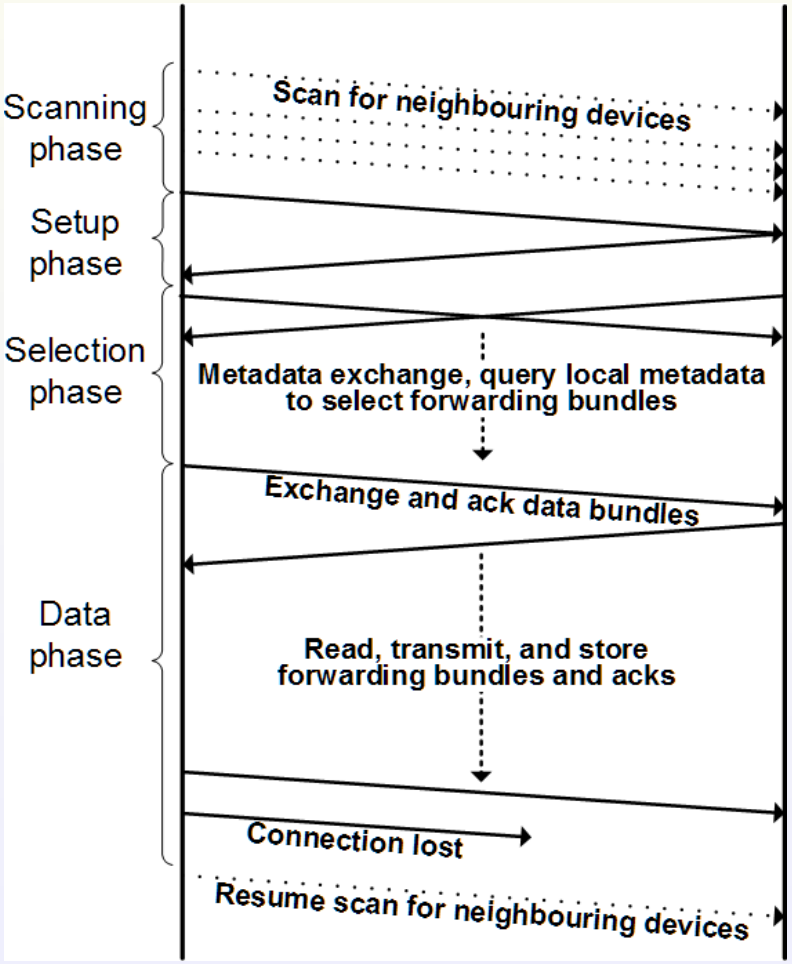
Identify and authenticate contact.

Selection Phase

Select bundles to forward.

Data Phase

Bundles read from persistent storage and transmitted.



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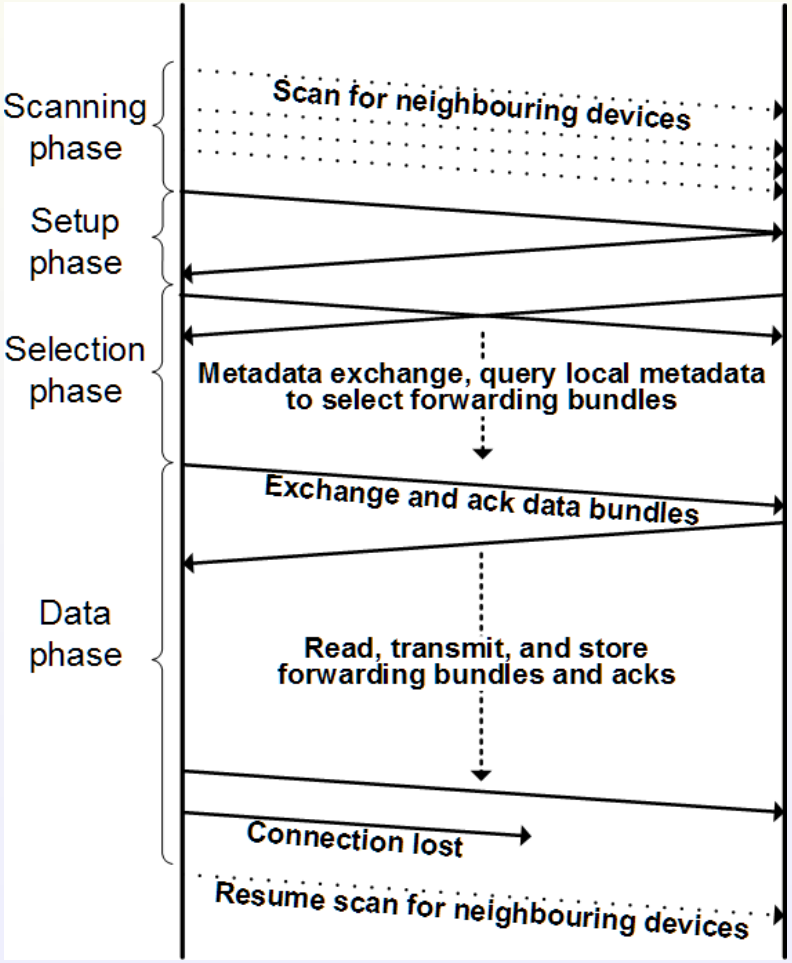

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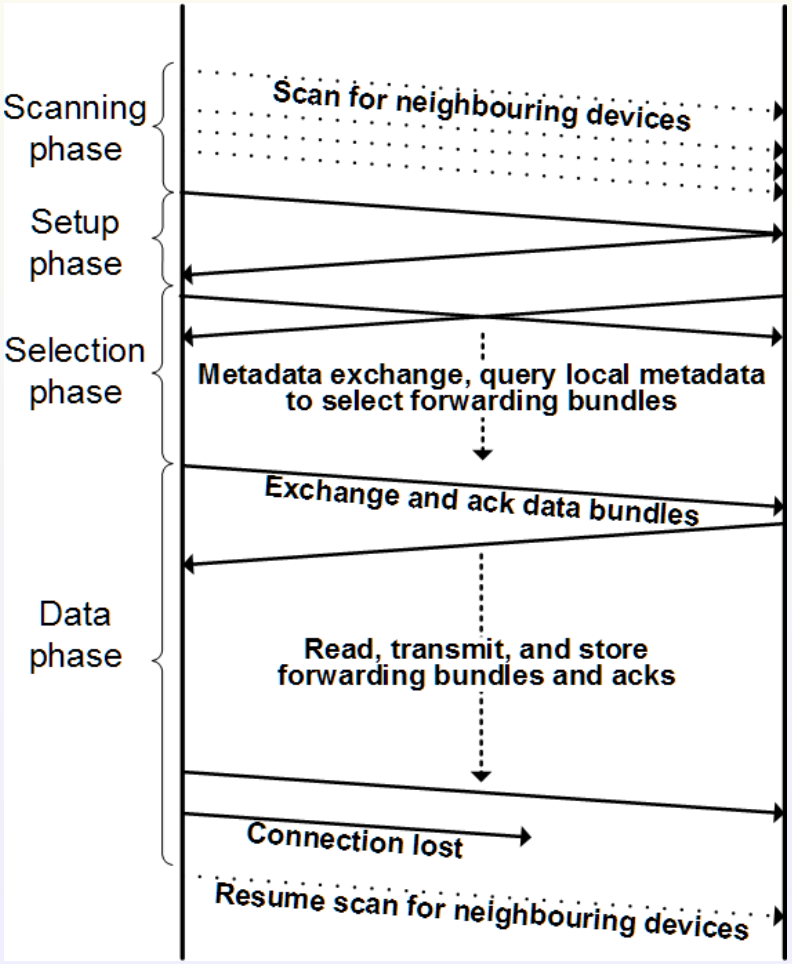

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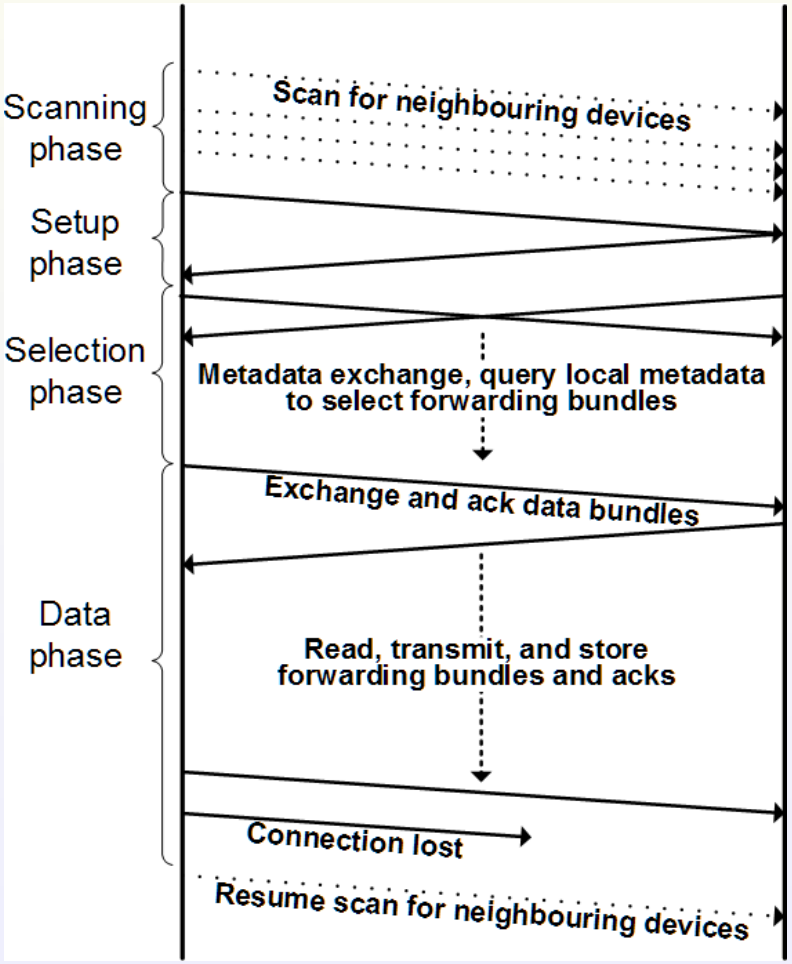

Design principles for opportunistic communication

- **Cache metadata.**
  - Querying a local database can be really expensive!
  - Use in-memory data structures.
- **Maximize the use of available memory and adapt to low memory conditions.**
  - Cache as much as possible!
  - Transferring bundles from memory can easily doubles wireless throughput.
- **Minimize redundant wireless data transfer.**
  - Connections are too short to waste.
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- **Explicitly distinguish between periods of connection and disconnection.**
  - During a connection: just transfer.
  - Exploit periods of non-connectivity to:
    - Refresh metadata.
    - Flush bundles from memory to disk.
- **Use hysteresis**
  - Lost connections may still be available, wait before closing them.
  - Being slow to react to events can improve performance.

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Current work

- Implementing these design principles in KioskNet 3.0.

Conclusions

- Developing software on low cost, low power constrained hardware differs from conventional PC environments.
- Although these principles are obvious in retrospect, they are not obvious to new system designers.
- Adding these properties to an existing system is non-trivial.
- Preliminary work has shown nearly an order of magnitude improvement in some circumstances.

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