DELAY TOLERANT NETWORK (DTN), FUNDAMENTAL & RESEARCHES

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BEGINNING OF DTN

- Late of 1990s DARPA had funded NASA, MITRE and others to develop a proposal for the Interplanetary Network (IPN).
- In 2002, it is started to adapt some of the ideas in the IPN design to terrestrial networks and coined the term *delay-tolerant networking* and the DTN acronym.

DTN VS CLASSIC NETWORK

Argh, those dreaded mobility! Always a big headache with nodes moving around getting out of range and stuff!

What a wonderful thing mobility is. It helps me spreading data.

Links and routes can fail anytime. Luckily I am prepared for this horrible incidents by using sophisticated route recovery and repair mechanisms!

You are a “Horrible incident”. Links will fail all the time. That’s just the way wireless networks are.

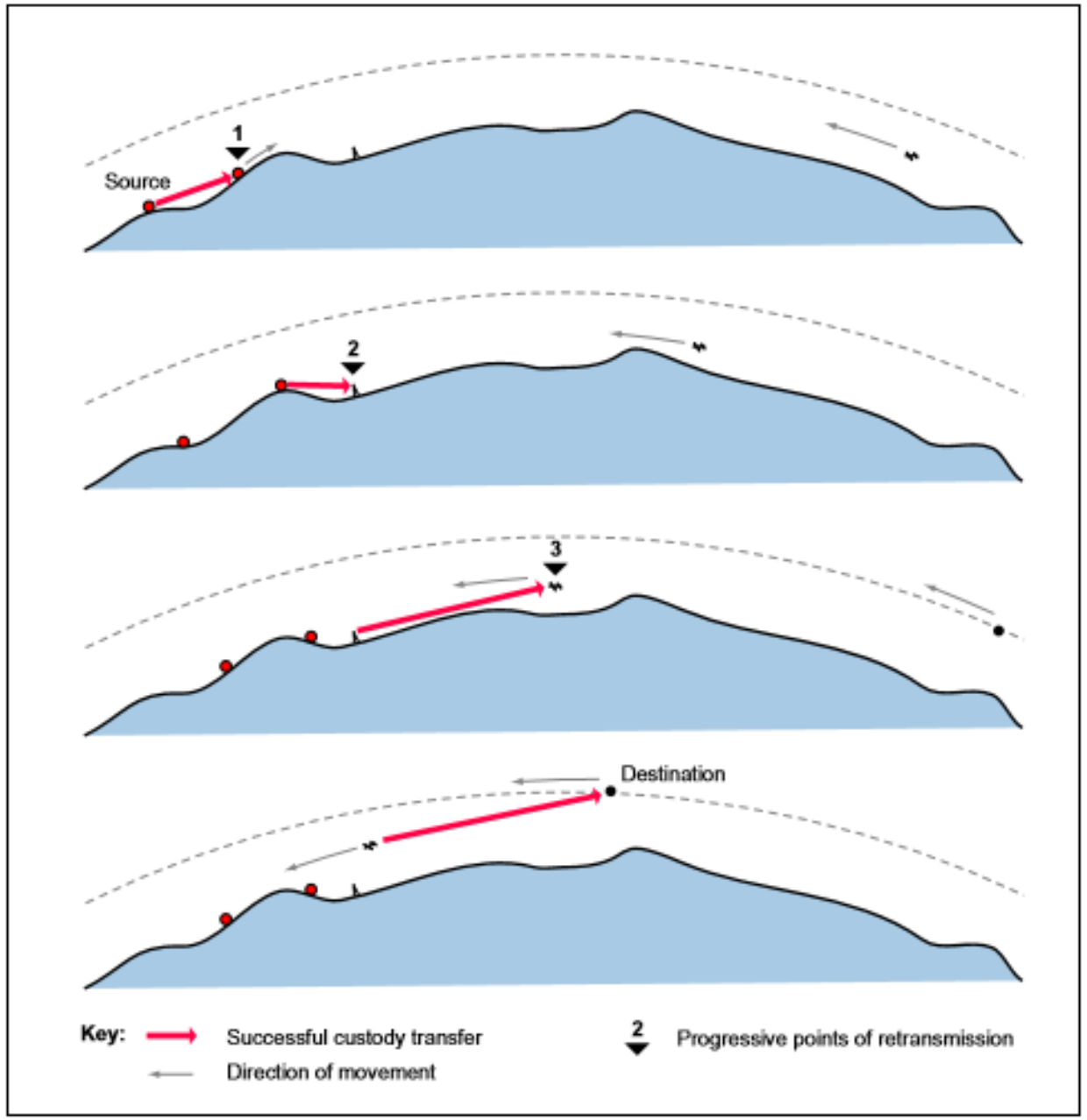
I have so many powerful ways of routing. I can find shortest paths, most reliable paths, use location, interest and much more to make your data arrive!

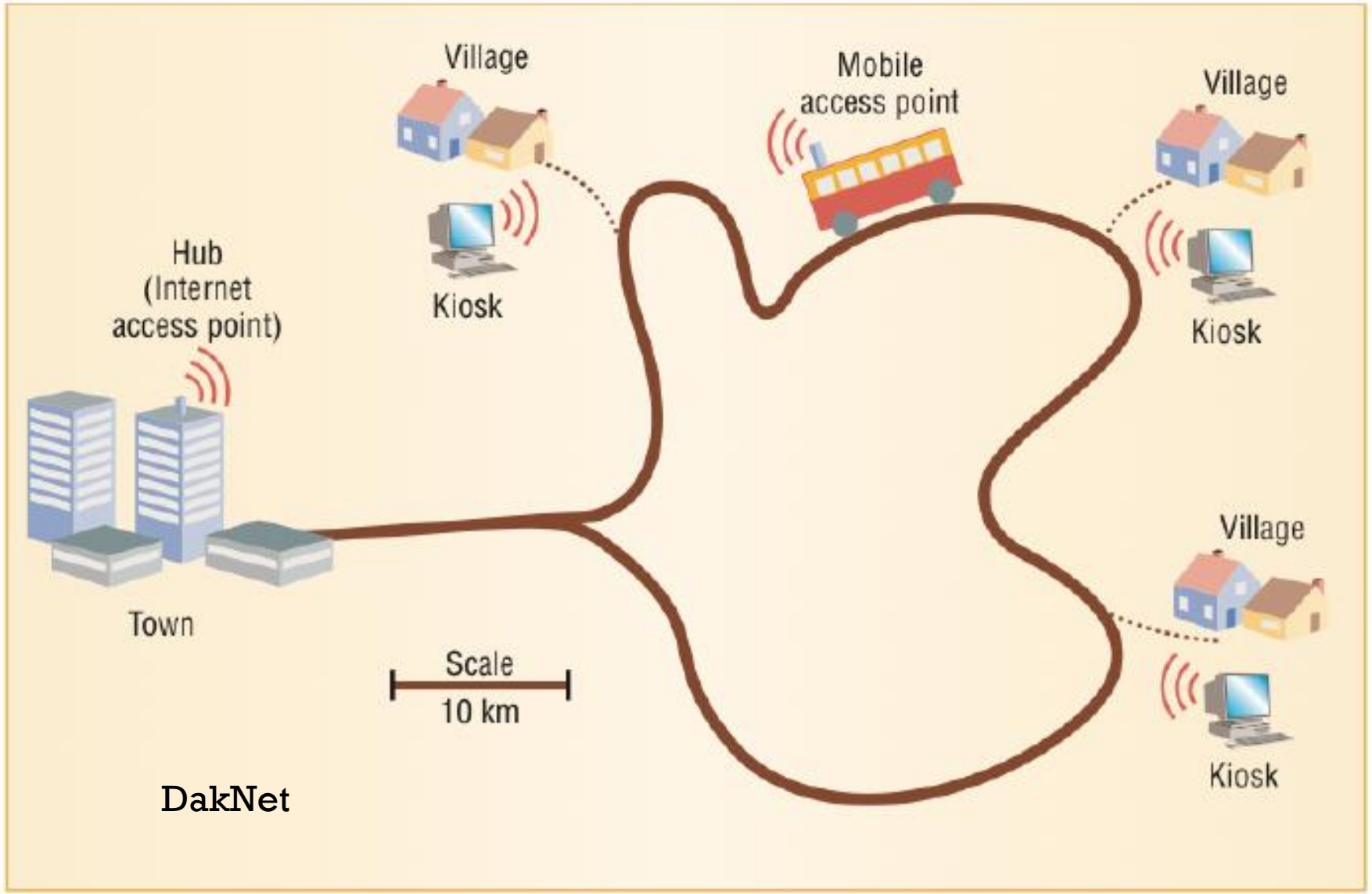
I can do all that. And if even with all those measures I can't deliver your packet directly, I will travel into the future to deliver it!

I am the standard. The whole internet builds on my principles. After all, most networks, even wireless ones are more or less reliable and connected, and this is my domain!

Networks for sissies? I am just as good as you in those networks!

Ordinary Networking	DTN Networking
Mobility is a challenge	Mobility is exploited
Link failures are handled as accidents	Failing links are considered as normal
Routing through space	Routing through space and time
The Standard	Superset of ordinary networking

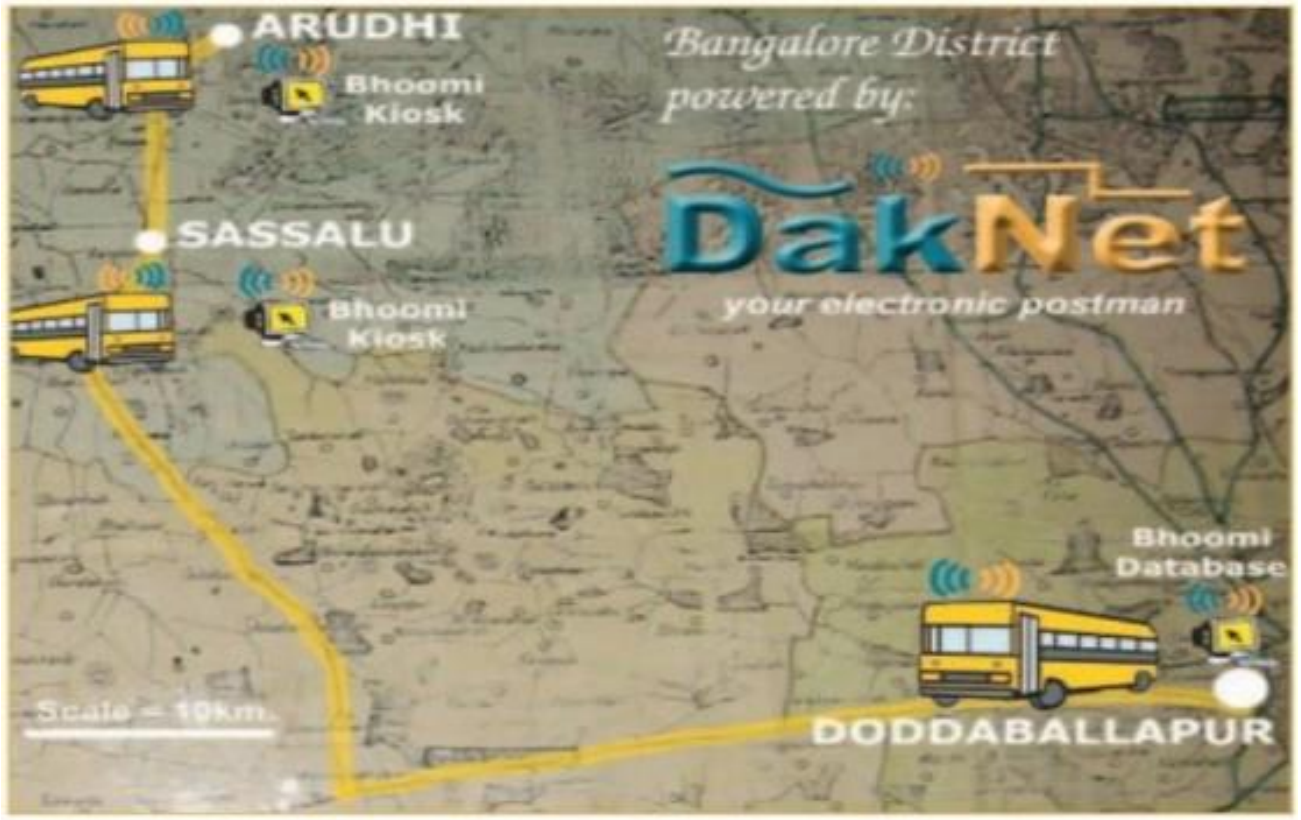

1
Source
2
3
Destination
Key:
Successful custody transfer
Direction of movement
2
Progressive points of retransmission


Village
Mobile
access point
Village
Hub
(Internet
access point)
Kiosk
Kiosk
Village
Town
Scale
10 km
Kiosk

DakNet

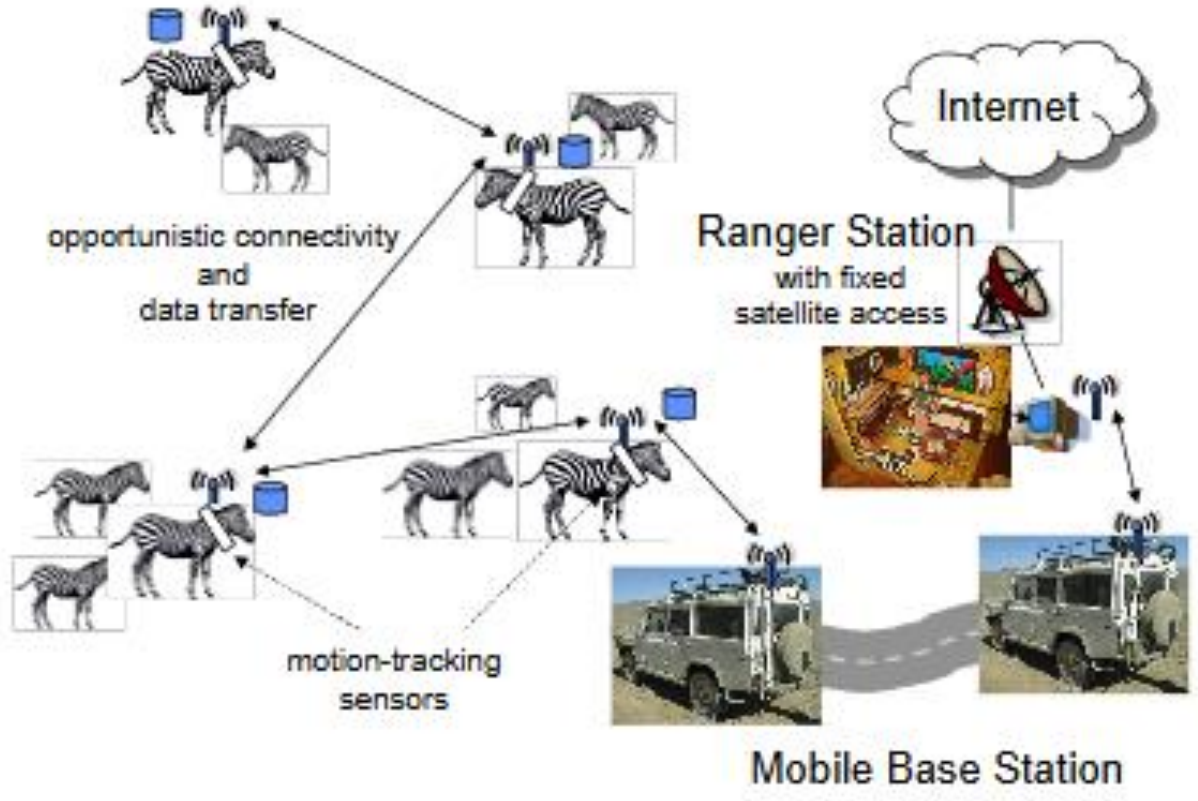
IMPLEMENTATION OF DTN

- DakNet → developed by MIT, Goal: Enable the use of internet applications in rural areas with no infrastructure



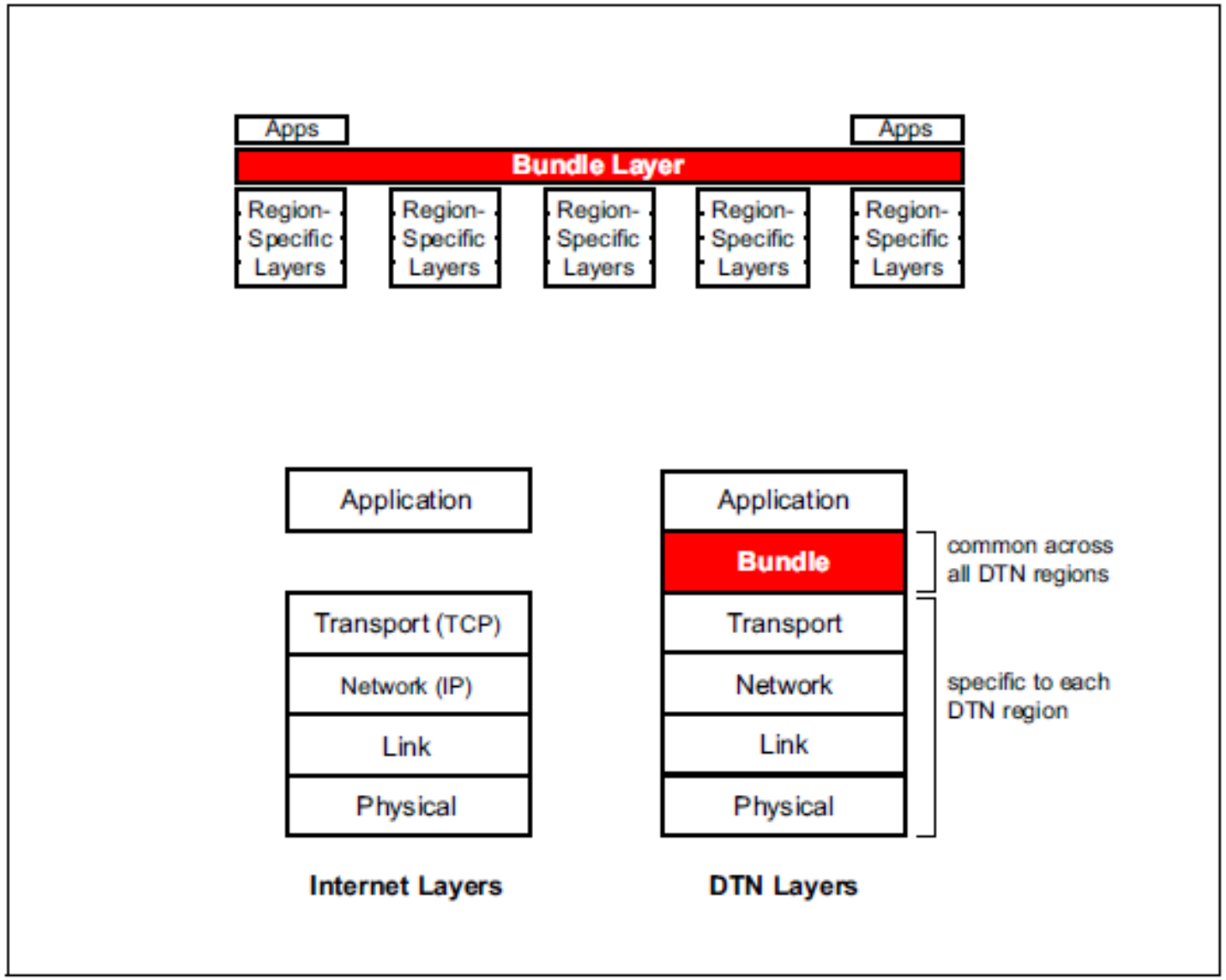
ZEBRA NET

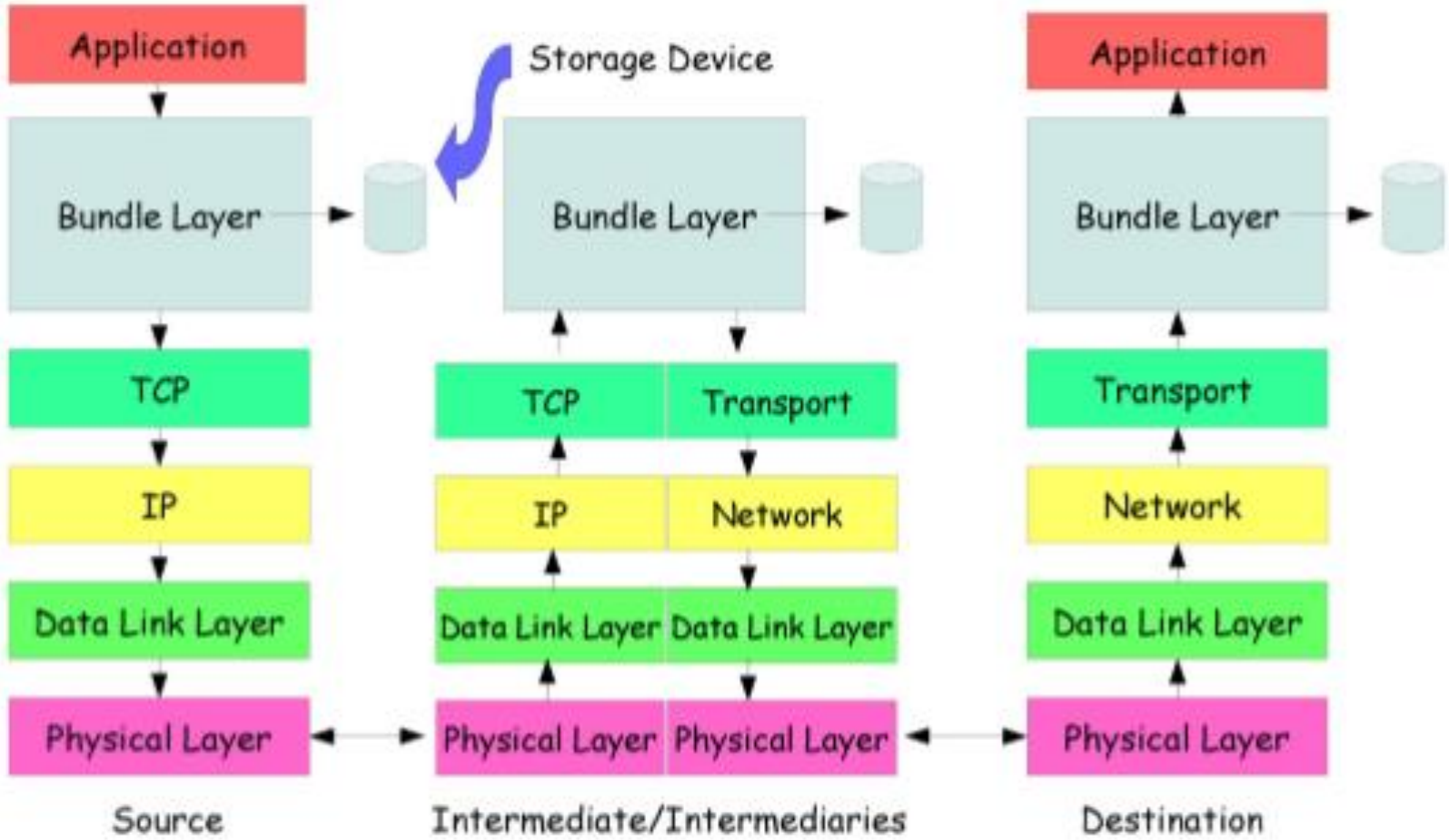
- To track zebra

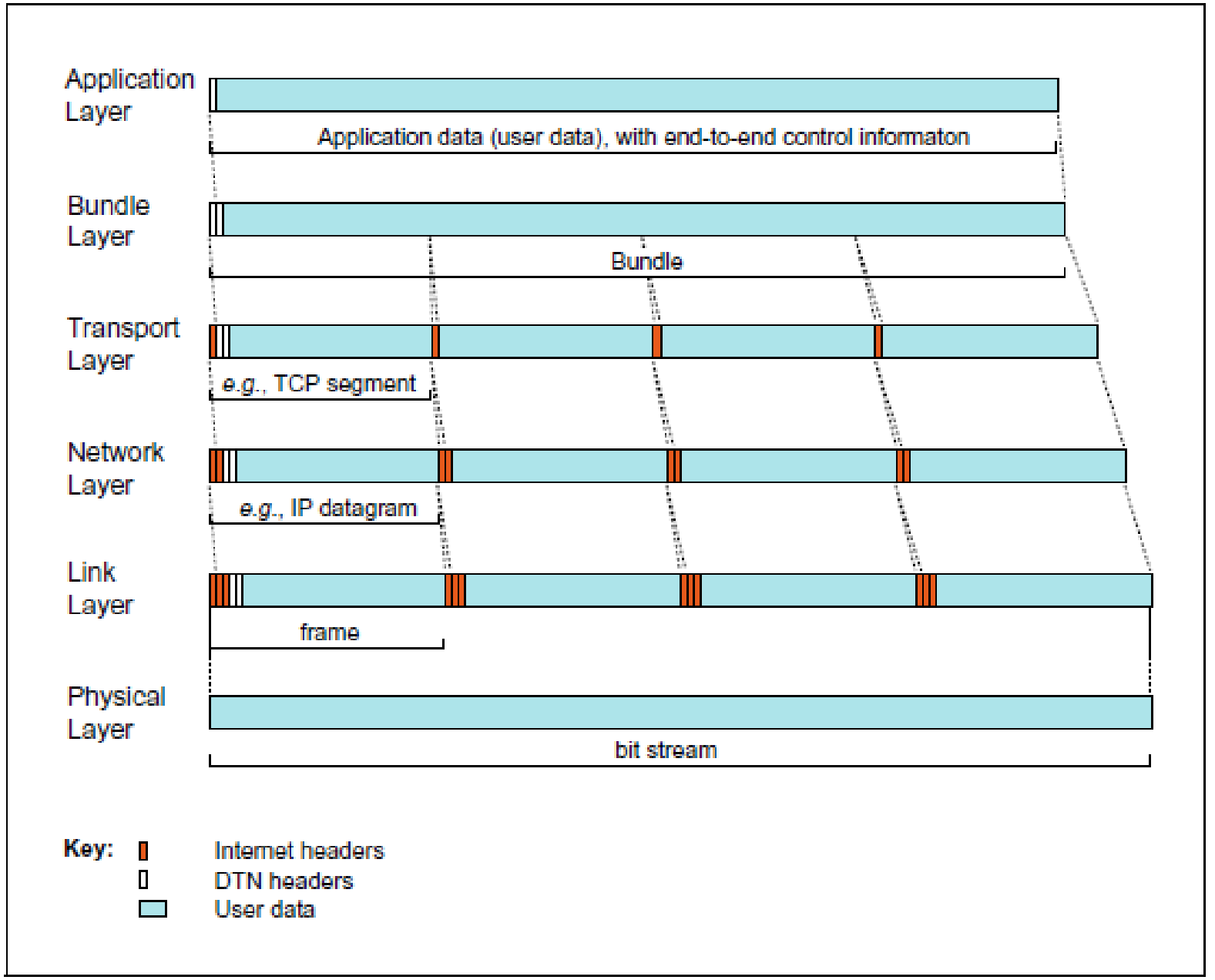


- OptraCom→ Pollution Monitoring in a large area, real-world experiments in the city of Braunschweig

The figure below illustrates the bundle overlay (top) and compares Internet protocol layers with DTN protocol layers (bottom).



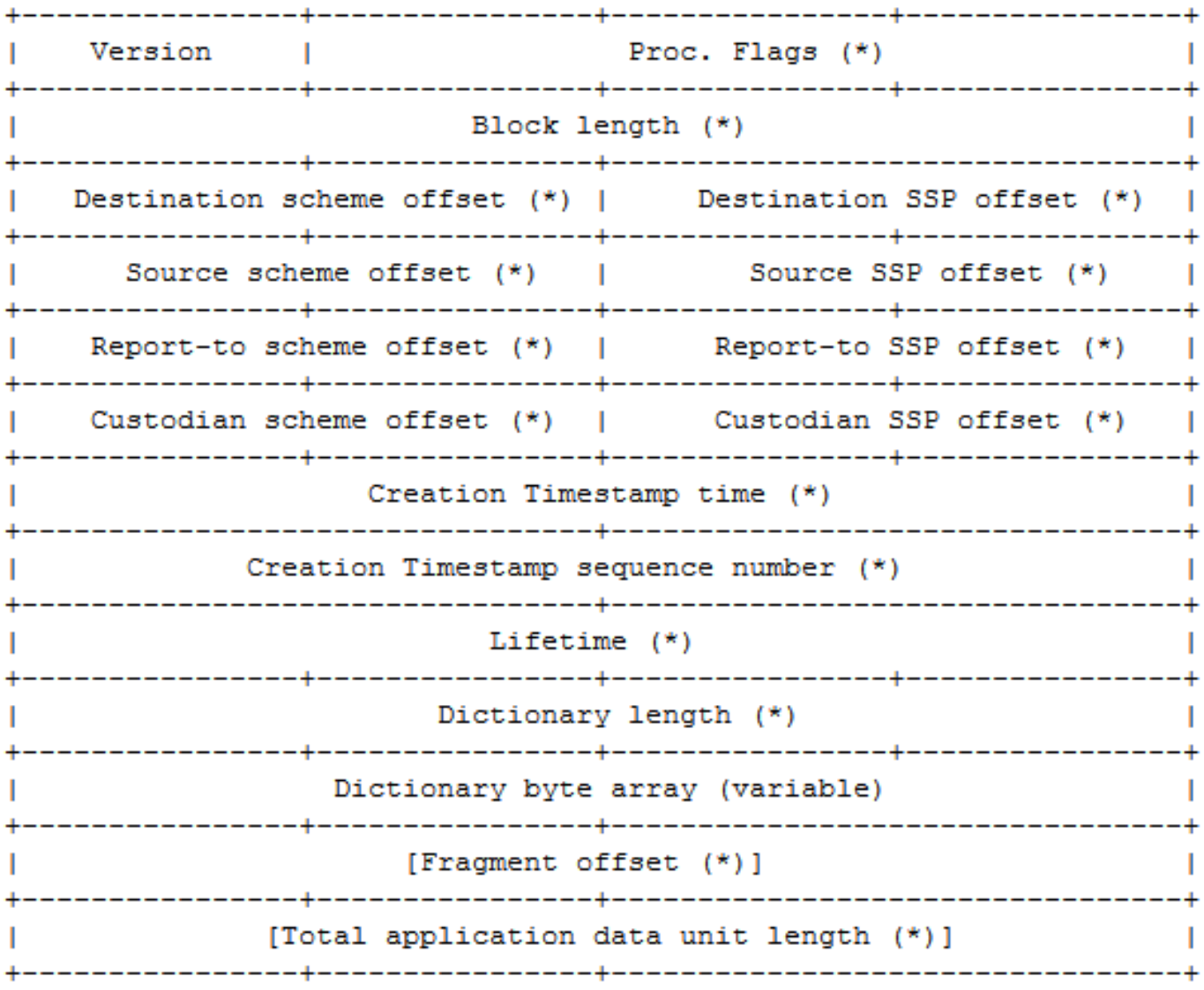

Application
Storage Device
Application
Bundle Layer
Bundle Layer
Bundle Layer
TCP
TCP
Transport
Transport
IP
IP
Network
Network
Data Link Layer
Data Link Layer
Data Link Layer
Data Link Layer
Physical Layer
Physical Layer
Physical Layer
Physical Layer
Source
Intermediate/Intermediaries
Destination


Application Layer
Application data (user data), with end-to-end control informaton
Bundle Layer
Bundle
Transport Layer
e.g., TCP segment
Network Layer
e.g., IP datagram
Link Layer
frame
Physical Layer
bit stream
Key:
Internet headers
DTN headers
User data

BUNDLE FORMAT

- Each bundle shall be a concatenated sequence of at least two block structure
- The first block must be a prymary bundle block
- The last block in the sequence must have the “last block” flag

Primary Bundle Block



PRIMARY BUNDLE BLOCK

- Contain basic information needed to route bundles to their destinations
- Version: A 1-byte field indicating the version of the bundle protocol that constructed this block.

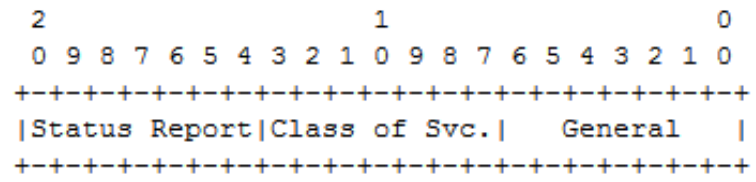


Figure 3: Bundle Processing Control Flags Bit Layout

The bits in positions 0 through 6 are flags that characterize the bundle as follows:

0 -- Bundle is a fragment.

1 -- Application data unit is an administrative record.

2 -- Bundle must not be fragmented.

3 -- Custody transfer is requested.

4 -- Destination endpoint is a singleton.

5 -- Acknowledgement by application is requested.

6 -- Reserved for future use.

The bits in positions 7 through 13 are used to indicate the bundle's class of service. The bits in positions 8 and 7 constitute a two-bit priority field indicating the bundle's priority, with higher values being of higher priority: 00 = bulk, 01 = normal, 10 = expedited, 11 is reserved for future use.

- Bundle Processing Control Flags: contains the bundle processing control flags

The bits in positions 14 through 20 are status report request flags. These flags are used to request status reports as follows:

14 -- Request reporting of bundle reception.

15 -- Request reporting of custody acceptance.

16 -- Request reporting of bundle forwarding.

17 -- Request reporting of bundle delivery.

18 -- Request reporting of bundle deletion.

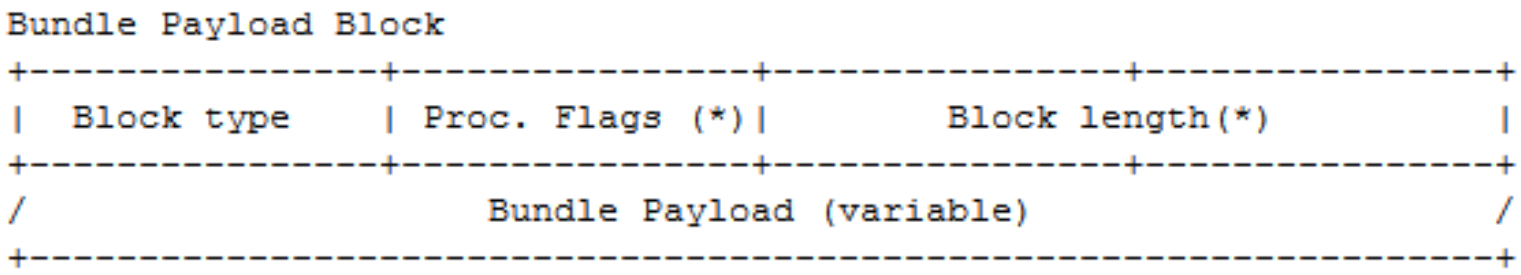
19 -- Reserved for future use.

- Block Length: contains the aggregate length of all remaining fields of the block.
- Destination Scheme Offset: contains the offset within the dictionary byte array of the scheme name of the endpoint ID of the bundle's destination, i.e., the endpoint containing the node(s) at which the bundle is to be delivered.
- Destination SSP Offset: contains the offset within the dictionary byte array of the scheme-specific part of the endpoint ID of the bundle's destination.
- Source Scheme Offset: contains the offset within the dictionary byte array of the scheme name of the endpoint ID of the bundle's nominal source, i.e., the endpoint nominally containing the node from which the bundle was initially transmitted.
- Source SSP Offset: contains the offset within the dictionary byte array of the scheme-specific part of the endpoint ID of the bundle's nominal source.
- Report-to Scheme Offset: The Report-to Scheme Offset field contains the offset within the dictionary byte array of the scheme name of the ID of the endpoint to which status reports pertaining to the forwarding and delivery of this bundle are to be transmitted.
- Report-to SSP Offset: The Report-to SSP Offset field contains the offset within the dictionary byte array of the scheme-specific part of the ID of the endpoint to which status reports pertaining to the forwarding and delivery of this bundle are to be transmitted.

- Custodian Scheme Offset: The "current custodian endpoint ID" of a primary bundle block identifies an endpoint whose membership includes the node that most recently accepted custody of the bundle upon forwarding this bundle. The Custodian Scheme Offset field contains the offset within the dictionary byte array of the scheme name of the current custodian endpoint ID
- Custodian SSP Offset: The Custodian SSP Offset field contains the offset within the dictionary byte array of the scheme-specific part of the current custodian endpoint ID.
- Creation Timestamp: contain bundel creation time and bundle's creation timestamp sequence number.
- Lifetime: The lifetime field is an SDNV that indicates the time at which the bundle's payload will no longer be useful, encoded as a number of seconds past the creation time.
- Dictionary Length: contains the length of the dictionary byte array.
- Dictionary: The Dictionary field is an array of bytes formed by concatenating the null-terminated scheme names and SSPs of all endpoint IDs referenced by any fields in this Primary Block together with, potentially, other endpoint IDs referenced by fields in other TBD DTN protocol blocks.

- Fragment Offset: If the Bundle Processing Control Flags of this Primary block indicate that the bundle is a fragment, then the Fragment Offset field is an SDNV indicating the offset from the start of the original application data unit at which the bytes comprising the payload of this bundle were located. If not, then the Fragment Offset field is omitted from the block.
- Total Application Data Unit Length: If the Bundle Processing Control Flags of this Primary block indicate that the bundle is a fragment, then the Total Application Data Unit Length field is an SDNV indicating the total length of the original application data unit of which this bundle's payload is a part. If not, then the Total Application Data Unit Length field is omitted from the block.

BUNDLE PAYLOAD BLOCK



- Block Type: The Block Type field is a 1-byte field that indicates the type of the block. For the bundle payload block, this field contains the value 1.
- Block Processing Control Flags: The Block Processing Control Flags field is an SDNV that contains the block processing control flags.
- Block Length: The Block Length field is an SDNV that contains the aggregate length of all remaining fields of the block - which is to say, the length of the bundle's payload.
- Payload: The Payload field contains the application data carried by this bundle.

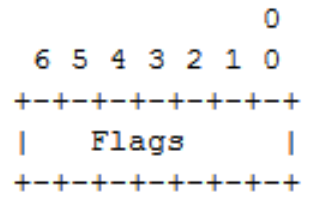


Figure 4: Block Processing Control Flags Bit Layout

0 - Block must be replicated in every fragment.

1 - Transmit status report if block can't be processed.

2 - Delete bundle if block can't be processed.

3 - Last block.

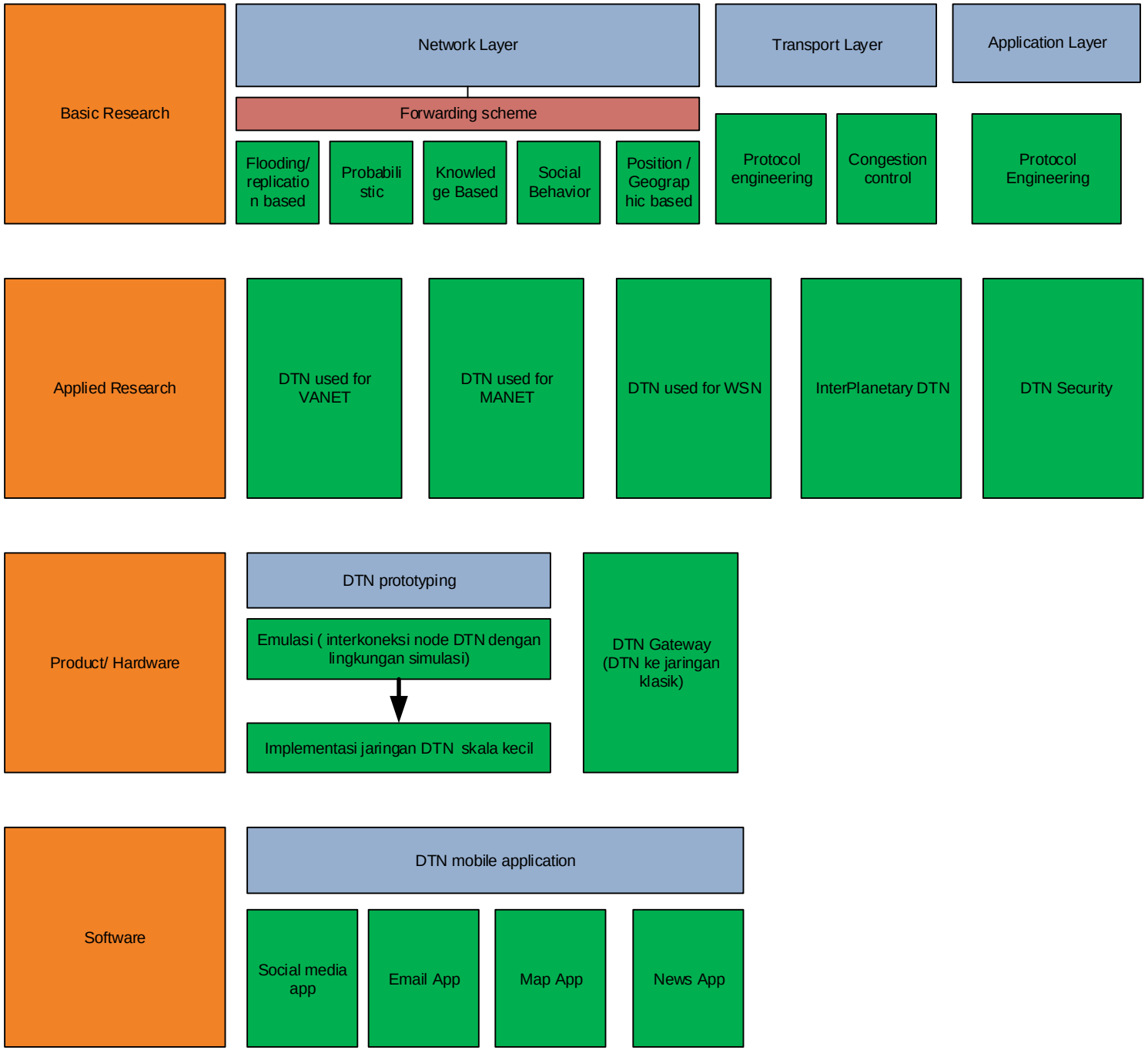
4 - Discard block if it can't be processed.

5 - Block was forwarded without being processed.

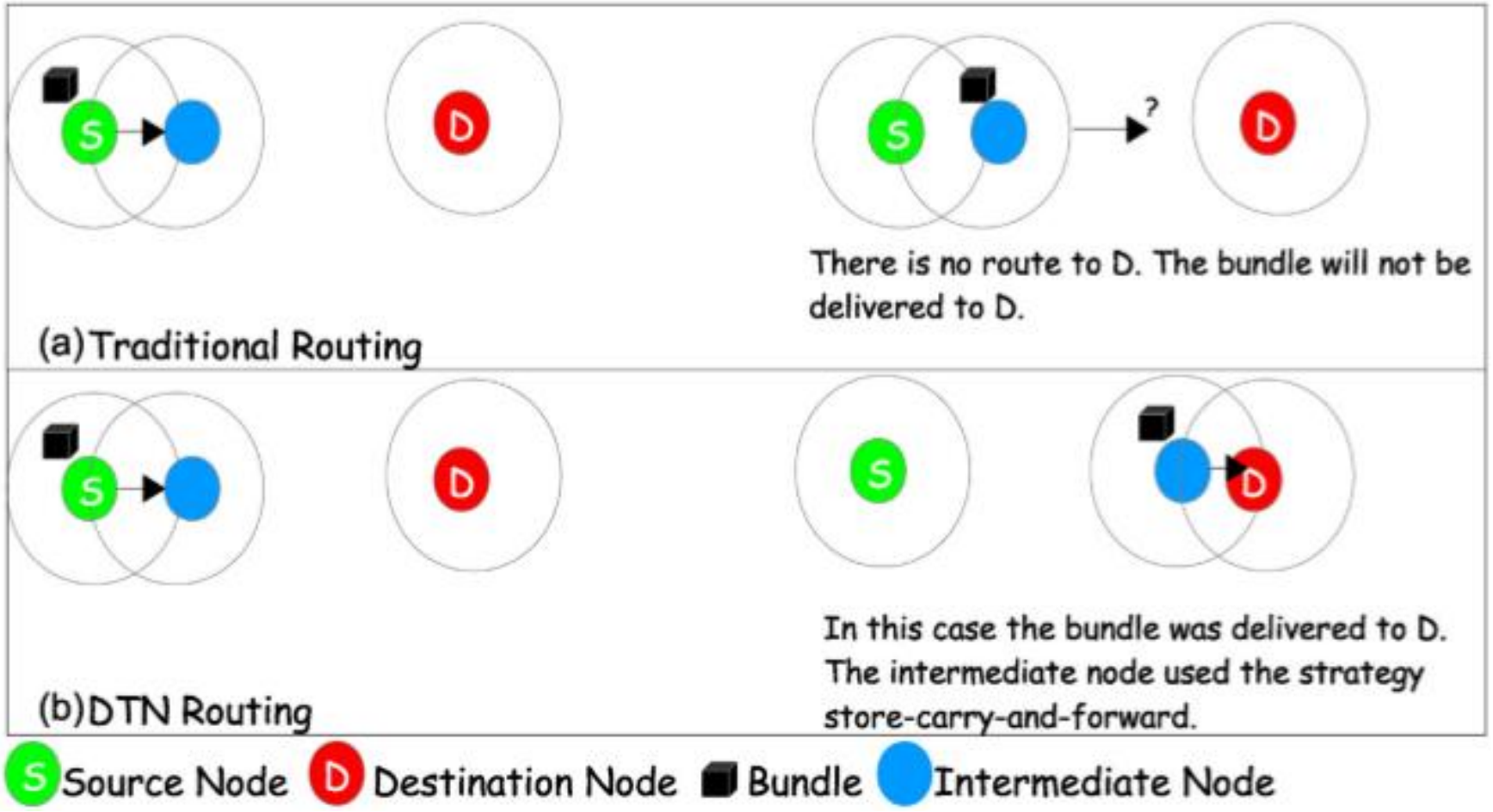
6 - Block contains an EID-reference field.

- Bundle includes:
  - Source's data
  - Control information, describes process, keeping and dropping data
  - Bundle header

RESEARCHES


Basic Research
Network Layer
Transport Layer
Application Layer
Forwarding scheme
Flooding/ replicatio n based
Probabili stic
Knowled ge Based
Social Behavior
Position / Geograp hic based
Protocol engineering
Congestion control
Protocol Engineering
Applied Research
DTN used for VANET
DTN used for MANET
DTN used for WSN
InterPlanetary DTN
DTN Security
Product/ Hardware
DTN prototyping
Emulasi (interkoneksi node DTN dengan lingkungan simulasi)
Implementasi jaringan DTN skala kecil
DTN Gateway (DTN ke jaringan klasik)
Software
DTN mobile application
Social media app
Email App
Map App
News App

DTN ROUTING


S
D
?
There is no route to D. The bundle will not be delivered to D.
(a) Traditional Routing
S
D
S
D
In this case the bundle was delivered to D. The intermediate node used the strategy store-carry-and-forward.
(b) DTN Routing
S Source Node
D Destination Node
Bundle
Intermediate Node

Routing algorithm

Goal: maximize delivery rate	Have to manage the use of storage	Strategy : store-carry-forward

SUBTYPE OF NON-ASSISTED ROUTING

Naive replication

- the routing protocols make multiple bundle copies without making any comparison between the contactable candidates for receiving the copy

Utility forwarding

- each node maintains a metric to qualify which contactable candidate will receive the bundle. There is no replication,and there is only a single copy of each bundle in the network.

Hybrid

- Spreading several copies of the same bundle provides more chances of it reaching its destination. Hybrid protocols combine the mechanism of the previous two approaches. The aim is to use the advantages of both.

EXAMPLE OF NAIVE REPLICATION

- Direct Delivery
- Epidemic
- Spray and Wait

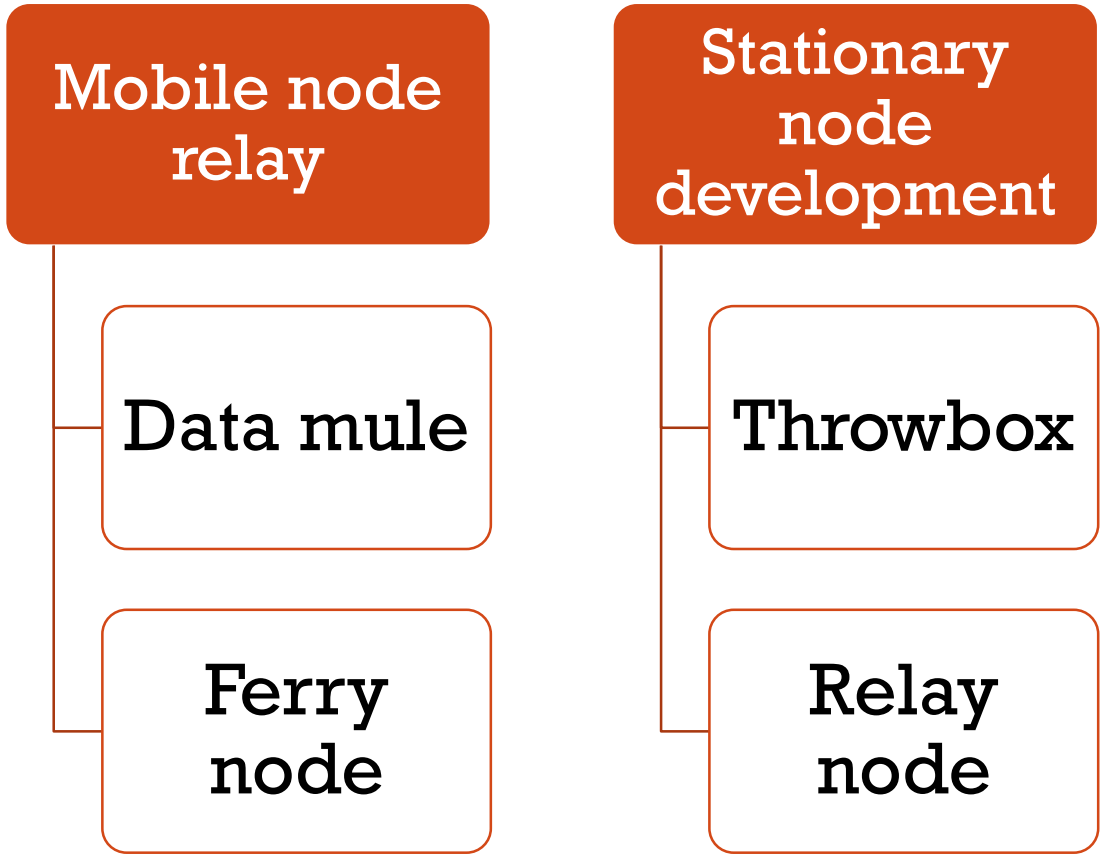
EXAMPLE OF UTILITY FORWARDING

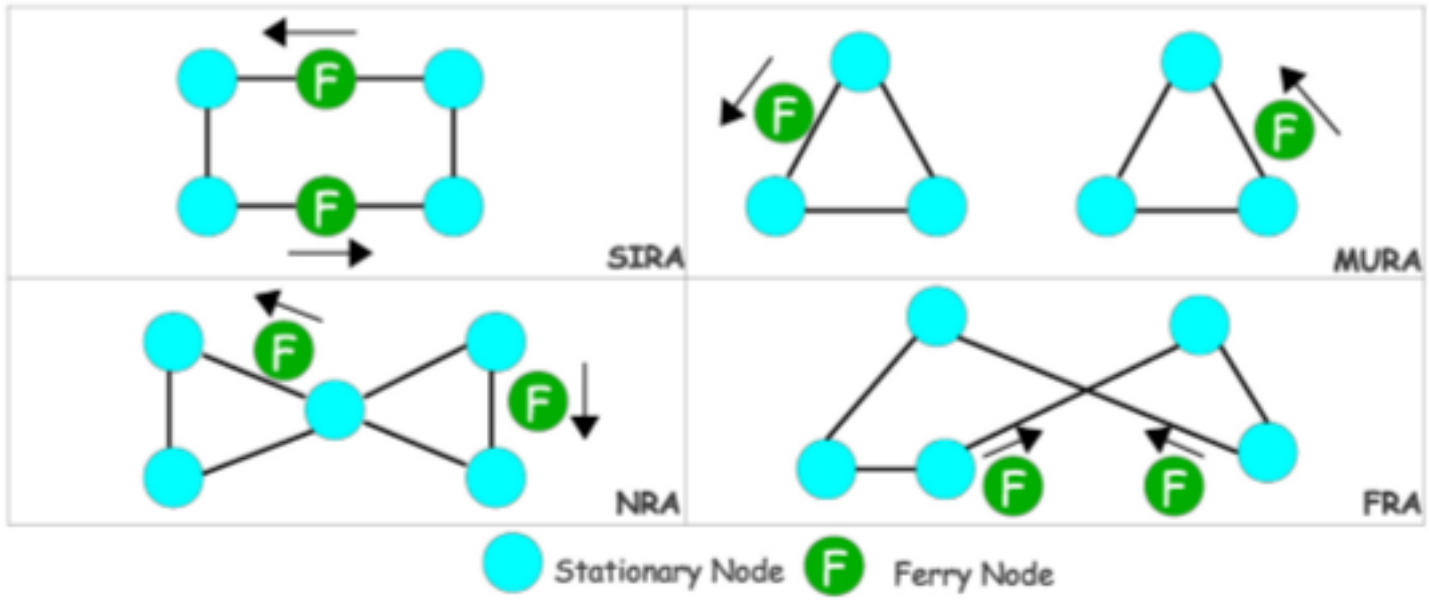
- First Contact
- Seek and Focus

EXAMPLE OF HYBRID

- PRoPHET
- MaxProp
- RAPID

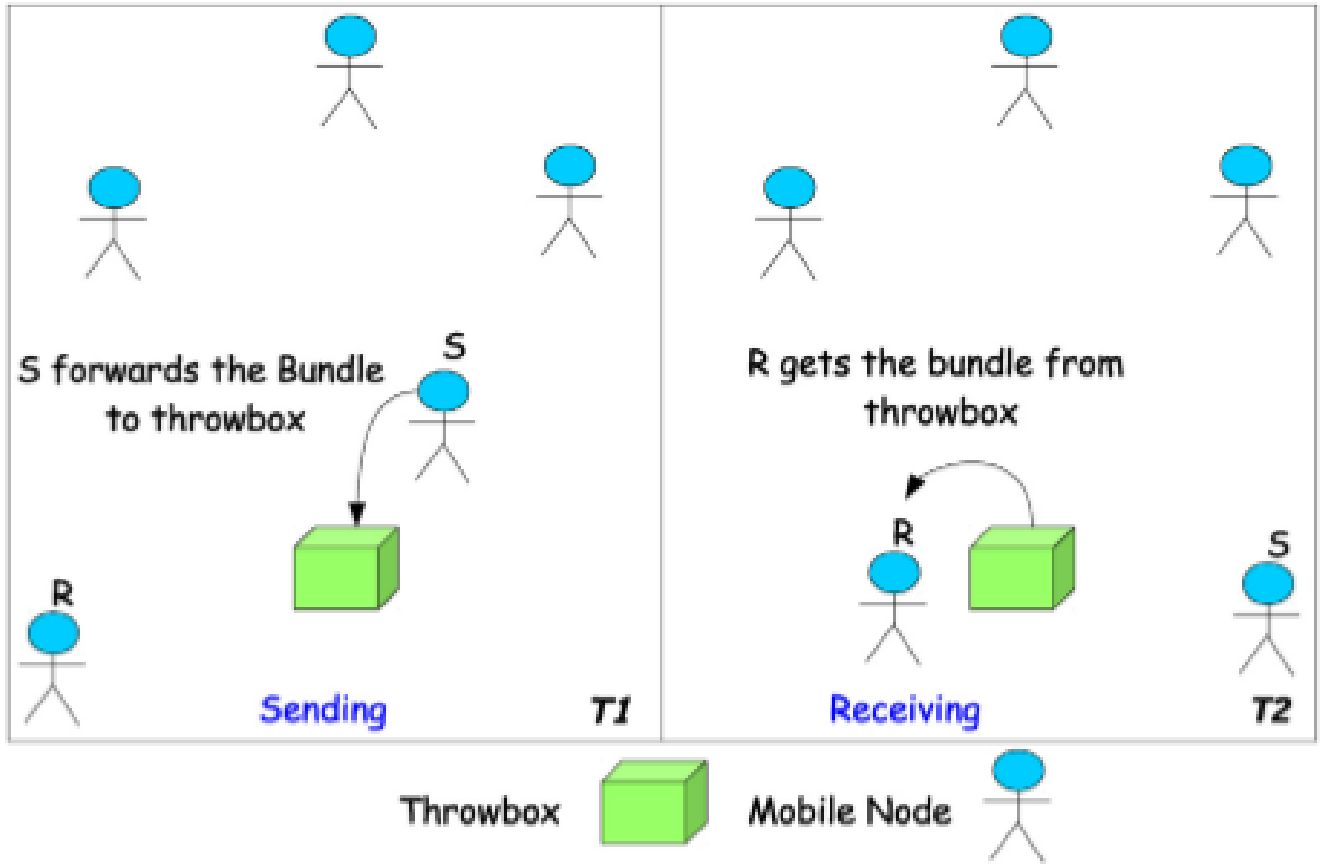
DTN ASSISTED ROUTING





Four approaches in forwarding and delivery bundles with multiple ferries.

- SIRA: the n MFs follow the same route at different times, these routes are calculated using heuristics based upon the logic of the traveling salesman problem (TSP)
- MURA: the MFs can take multiples routes, but in this case, the MFs do not exchange data mutually. In order to compute the routes, the same algorithm can be applied to SIRA.
- NRA: the MFs can exchange data using stationary nodes by forwarding the bundles. In NRA,the environment is divided into a set of cells that form a grid, whereby the MFs have the role of carrying the data in the cells, and the stationary nodes, the role of transmit data between cells.
- FRA: unlike the NRA, MFs can directly exchange data. FRA needs to synchronize the MFs, so that they can meet to achieve transfer bundles. It is unlike NRA, which uses stationary nodes to communicate between the MFs without needing synchronization to transfer bundles.



DTN routing using throwboxes.

PROTOCOL ENGINEERING

- Keep TCP connection open during disconnection → PCMP (Persistent Connection Management Protocol)
- HTTP over DTN transport --> The natural approach is to perform a one-to-one mapping of HTTP requests and responses onto bundles.
- Application layer bundling → When intermediaries are used several requests or responses may be bundled to reduce overhead and improve efficiency. So, all the resources required to display a web page could be retrieved upon a single request and returned in bundled format, ideally a single response → MHTML [5]

CONGESTION CONTROL

- Buffer management
- Dropping policy

REFERENCE

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2. Forrest Warthman. Delay Tolerant Network: A Tutorial. 2003
3. João Gonçalves Filhoa, Ahmed Patela,b, Bruno Lopes Alcantara Batistaa, Joaquim Celestino Júnior, A systematic technical survey of DTN and VDTN routing protocols , 2016
4. https://tools.ietf.org/html/rfc5050, diakses tanggal 2 februari 2017, 10.57
5. J. Palme, A. Hopmann, and N. Shelness, "MIME Encapsulation of Aggregate Documents, such as HTML (MHTML)," RFC 2557, March 1999.

SELAMAT MENELITI