Delay-Tolerant Networking for Smart-phones

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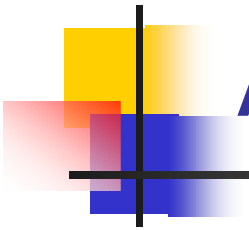
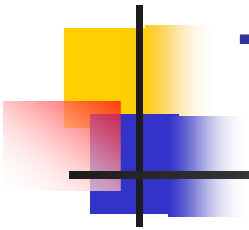


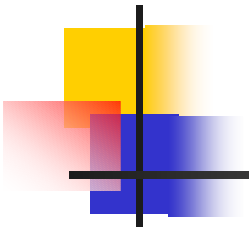
Agenda

- Overview of Internet protocols
  - Pros and cons...
- Emerging Networks
  - New paradigms, new issues...
- What's DTN?
  - How does it try to solve the issues?
- DTN protocols
- Implementation architecture
- Conclusions



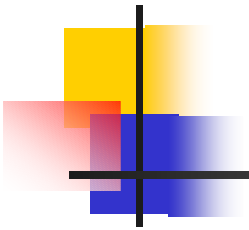
The Internet and TCP/IP

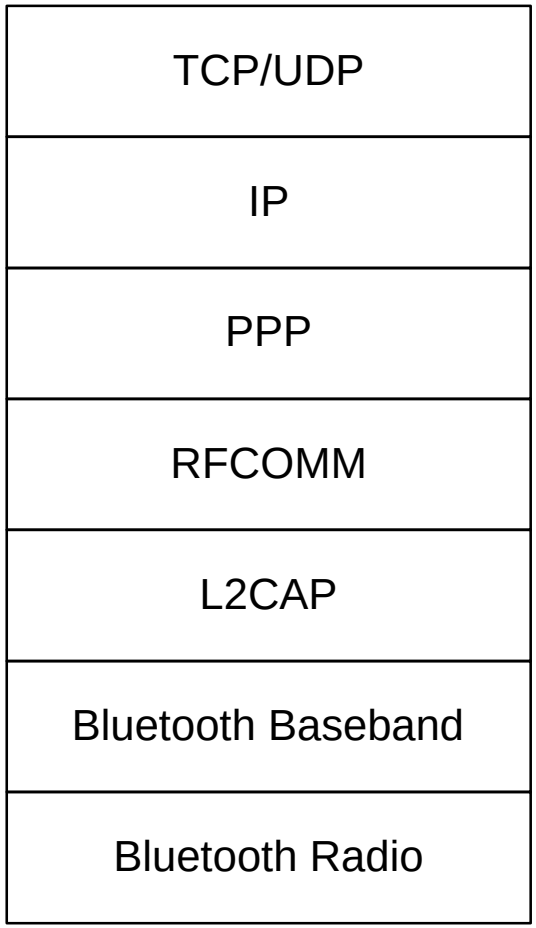
- Internet – the popular and fast growing communication medium
  - Web, E-mail, Chat, VoIP, Streaming...
- Example applications
  - Education, Research
  - E-Commerce
  - Entertainment
  - Communication

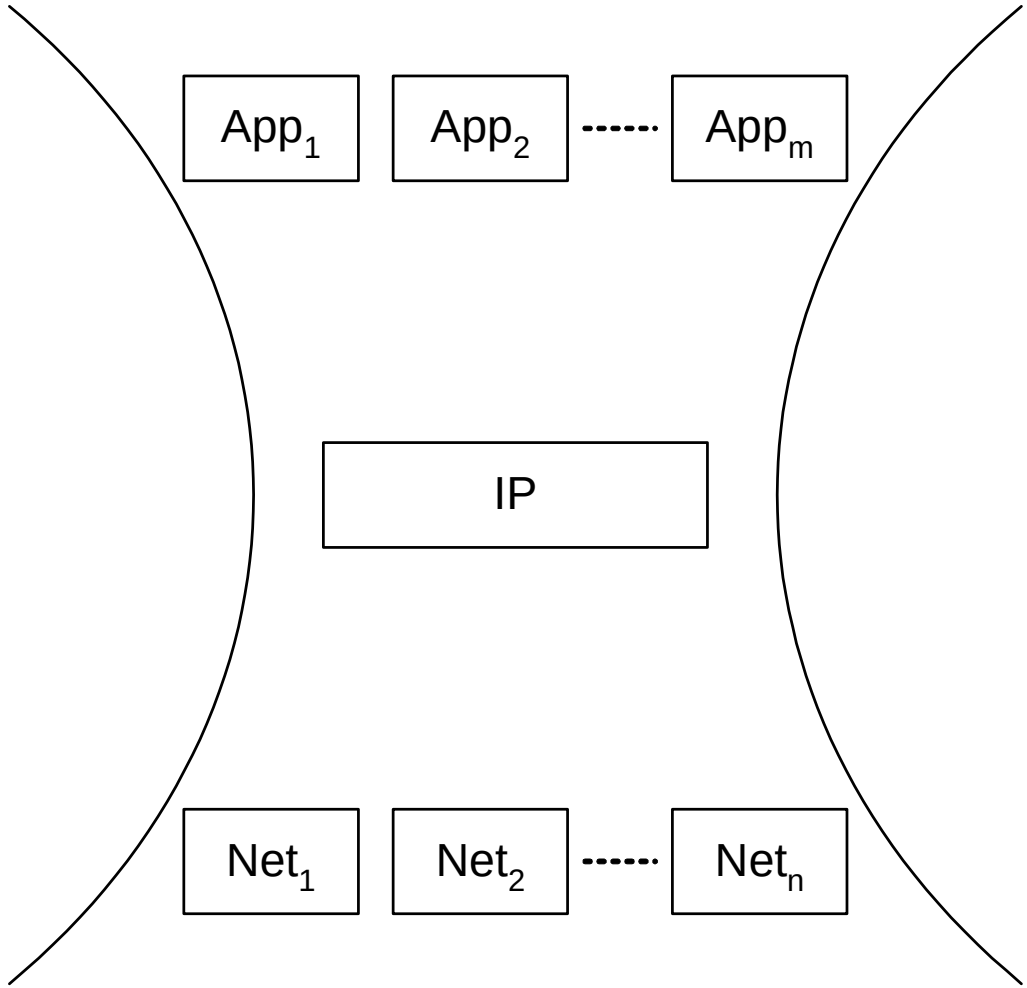


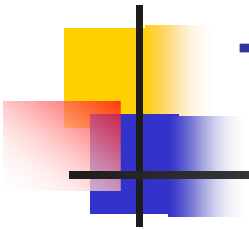
IP is everywhere...

- Changing and leading other communication paradigms
  - IP in 3G & 4G
- Inter-networking of networks
  - Cellular, Wireless, Fixed
  - PANs, LANs, MANs, WANs
- Hour-Glass model



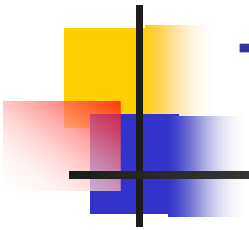

TCP/UDP
IP
PPP
RFCOMM
L2CAP
Bluetooth Baseband
Bluetooth Radio


App1
App2
Appm
IP
Net1
Net2
Netn



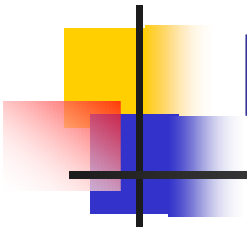
TCP/IP Architectural Principles

- End-to-end connectivity
- End-to-end reliability
- Small end-to-end errors in physical links
- End-to-end congestion control
- End-to-end flow control
- Frequent end-to-end message exchange
  - TCP signaling (SYN-ACK-FIN)
  - Conversational applications (HTTP, FTP etc.)
- In one phrase, Internet is an **END-To-END** mechanism.



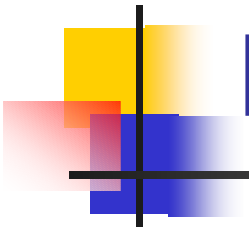
TCP/IP Issues

- IP address for routing and node identification
  - HIP; very recent, not deployed yet
- Early binding (name to address translation before communication begins)
  - One IP address for one node (IPv6)
- Poor recovery on network failures
  - Establish end-to-end connection again?
  - Network nodes discard all packets on system crash.



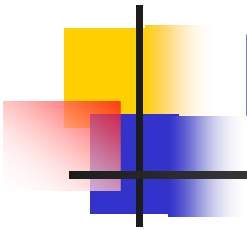
Emerging Networks

- Extreme, stressed and challenged environmnets
- High error rates
  - Wireless networks (TCP performance degrades)
- Intermittent connectivity
  - Sparse ad hoc networks e.g. mobile devices, military battlefield equipment (frequent interruptions)
  - Sensor-nets (infrequent access)
  - Low Earth Orbit Satellites (periodic)
- Longer delays
  - Satellite connections
  - Deep space communication (Star-Trek ☺)



Experimental networks...

- Nomadic networks e.g. fast moving vehicles (very short connection time)
- Data-buses, data-mules, message ferries
  - Internet for remote areas, e.g. villages, islands
- End-to-end model breaks in all these scenarios...
  - Can’t use TCP/IP; degrade of fail at all...
  - Separate solutions for separate networks
    - TCP enhancements for wireless networks

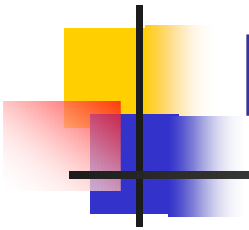


Delay-Tolerant Networking

- Tries to fix many of the problems
  - No end-to-end assumption
  - Better recovery on device failures
  - Long delays
  - Minimum end-to-end message exchanges
- A single solution for a variety of networks
  - Interplanetary Internet (deep space communications)
  - Ad Hoc and terrestrial wireless networks
  - Sensor networks
  - Nomadic networks

DTN Architectural Principles

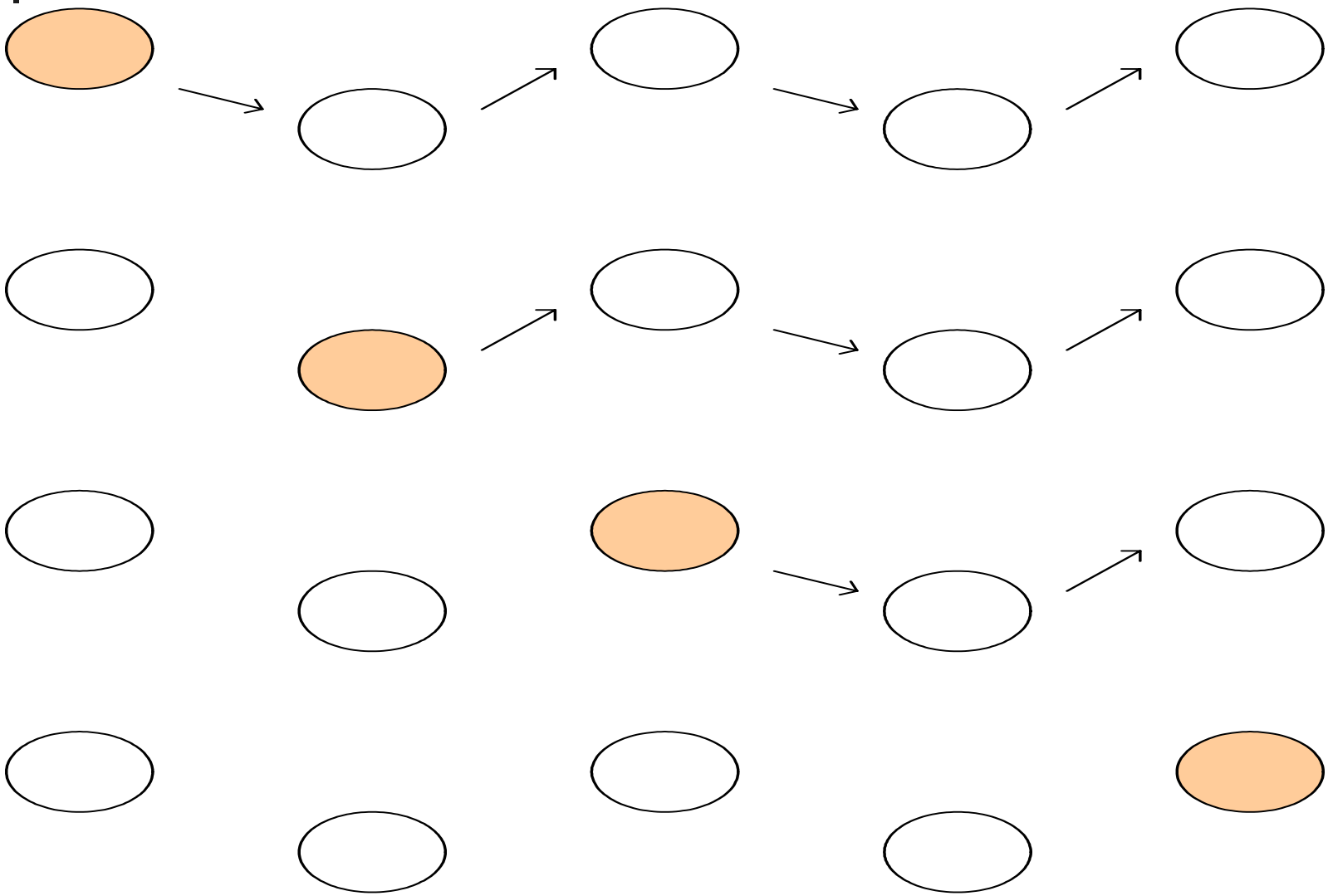
- An overlay network
  - “Bundle” layer, above transport layer and below application layer to inter-network different heterogeneous networks
    - multiple communication links, topologies
- Variable length messages containing complete data and meta-data *bundled* into one (ideally)
  - Hence called bundle layer
- End-to-end message delivery
  - Virtual message-switching (in contrast with packet-switching)
  - Improved routing decisions made for whole message, rather than packets (based on QoS, priority etc.)



DTN Architectural Principles

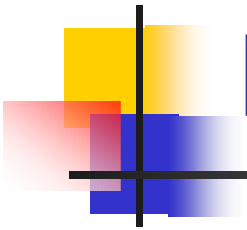
- E-mail style store-and-forward architecture
  - Persistent storage to combat network failures, device reboots
- Custody transfer of message, from source to nodes in the network
  - Custody gradually moves “closer” to destination
  - Custodian is responsible for retransmissions (E2E model is broken)

Custody Transfer



Addressing-Naming Schemes

- End-point Identifier (EIDs) based upon standard URIs
  - Defines own URI scheme (dtn://mypc.hut.fi/email)
- Late-binding
  - Routing based on EIDs
  - Name to address translation is performed at quite later stage in the network
- Multiple nodes can register for one EID and one node may register for multiple EIDs
  - Multi-homing and mobility



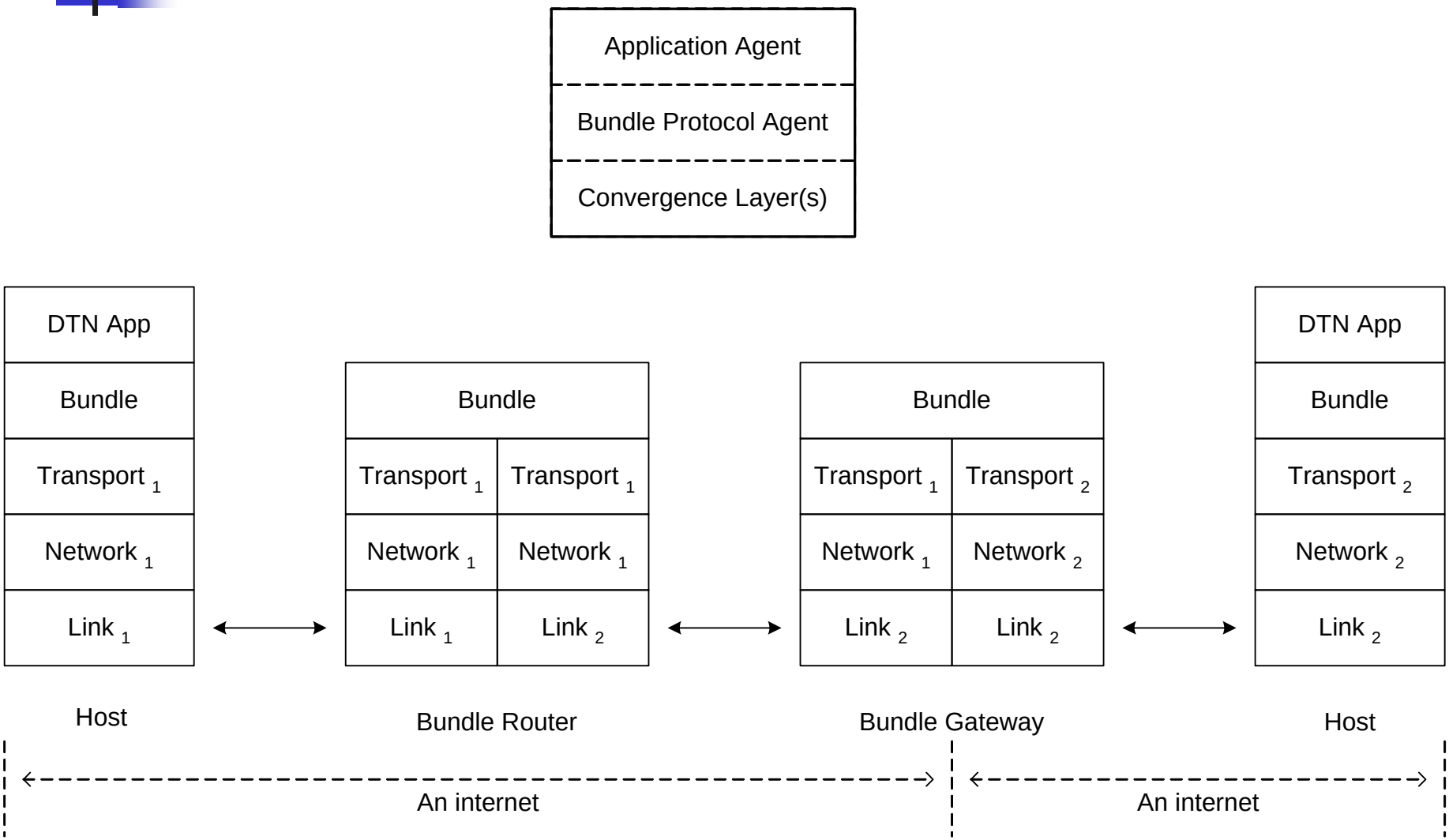
Routing

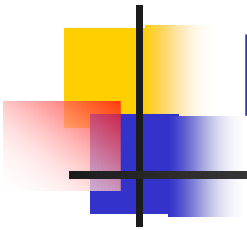
- Multiple links for different underlying networks
  - Persistent, on-demand : (always connected)
  - Scheduled, opportunistic : (intermittent)
- Multi-graph network topology
  - Each link with different capacity, availability (time) and direction (symmetric, one way)
- Multi-path routing (in contrast with best route selection in Internet)
- “Intelligent” routing - Active research area
  - Probabilistic, statistical; advanced ad hoc routing algorithms and protocols

Non-conversational paradigm

- Applications restructuring
  - To minimize end-to-end transactions
- Gateways, proxies for existing applications
  - E-mail gateway
- New application design strategies
  - Web over DTN (bundle all related pages into one message
  - FTP over DTN (send login, password and other meta-data bundled with data

Protocol Stack & Nw Hierarchy



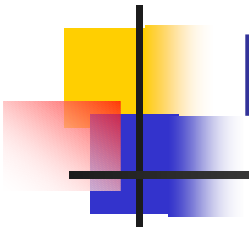


Protocol Features

- Flexible and extensible
  - A basic header and extension headers
- Self-Delimiting-Numeric-Values
  - No fixed size fields for lengths (variable headers)
- Dictionary block for EIDs
  - EIDs can also vary in length, so pointers within a buffer are (re)used
- Status reports
  - Like ICMP, but both for positive and negative feedbacks

Design and Implementation for Symbian OS

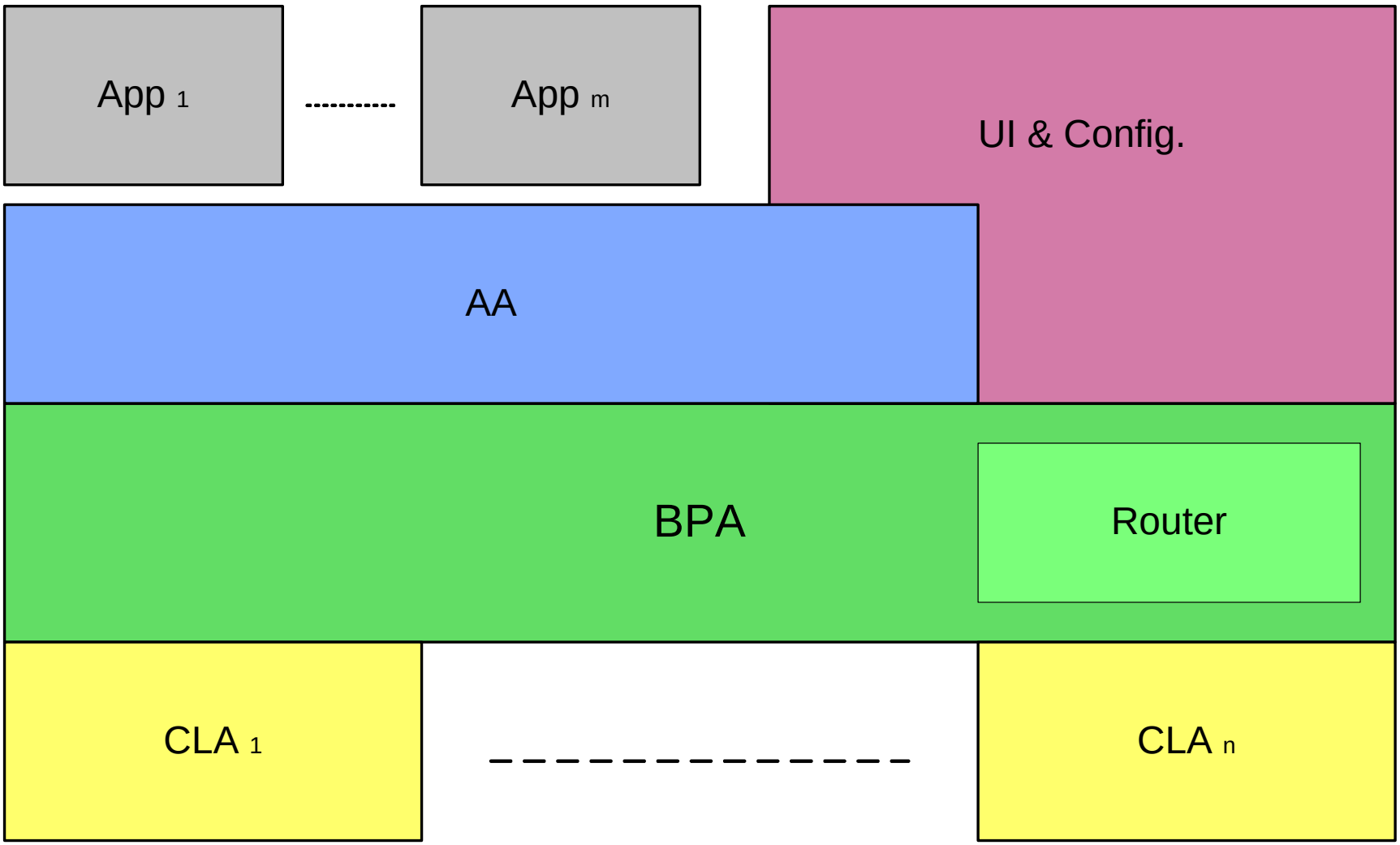
- User tend to carry mobile devices all the time
  - Social networks are formed when people meet
  - Statistical routing techniques in social networks - an active research area
- Intermittently-connected ad hoc networks
- Reference implementation is very large and hard to port
  - A light-weight DTN framework for smart-phones
  - Can be integrated into OS itself
- Smart-phones are equipped with multiple communication technologies
  - New experimental CLAs for Bluetooth, GPRS, messaging



Programming for Symbian OS

- C++, the native programming language
  - Efficient, optimized applications and server components
- Non-preemptive multitasking
  - Active Objects; no synchronization required
- Constraint devices, less memory, low power
  - Compact code
  - In-place execution
- Optimized API and library functions
  - No STLs
  - Asynchronous OS services
- Client/server framework for IPC

Implementation Architecture

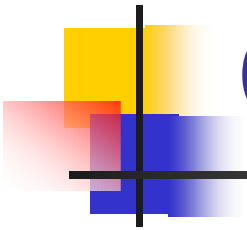


Implementation Details

- Design of architecture for Symbian OS
  - Generic, extendable, optimized design
- Application agent and sample application for file transfer
- Bundle protocol agent
  - Static routing, flooding
- Convergence layers
  - TCP, Bluetooth
- Socket like native IPC mechanism
  - Runs as a server application
  - offers API for client applications

Testing & Demo Setup

- Inter-operability testing with reference implementation
- Code released under GPL
  - http://www.symob.net/dasm.htm



Conclusions

- DTN is an emerging paradigm for challenged networks
  - Tries to solve many issues found in conventional Internet protocols
  - The implementation can be extended with new features / protocols
- Policy based statistical, probabilistic routing algorithms
- DTN-capable application design
- New convergence layers
- Security issues
- Real-world statistical analysis

Thank you...

- For your patience ☺
- Special thanks to Prof Ott
- Questions?