Towards a Unified Radio Power Management Architecture for Wireless Sensor Networks

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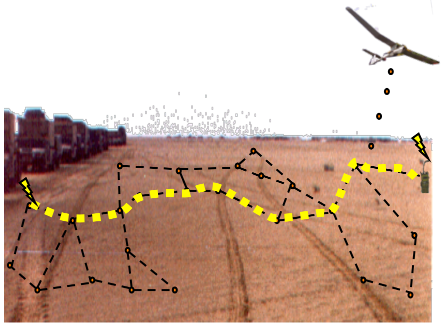
Wireless Sensor Network Applications

Habitat monitoring



Intruder Detection

Structural monitoring

Healthcare

- Long lifetime requirements: months to tens of years
- Limited power supplies: batteries, small solar panels
- Must keep power consumption to a minimum

Wireless Sensor Network Platforms

- Extremely resource constrained
- Sensors: acoustic, magnetic, light, temperature…..
- Memory: 4-10KB data, 128-256 KB program
- Flash: < 1MB non-volatile storage capacity
- Radio: < 250 Kbps
- Limited power supply: 2AA batteries
  - Lifetime < 1 week if continuously active

Mica2

MicaZ

Tmote

EyesIFX

BTNode

Problem

- Radio communication accounts for majority of energy consumption in all of these applications and platforms
  - ⇨ Explosion in radio power management research
- Emerging protocols make different assumptions about application workload and performance requirements
  - ⇨ No single protocol is suited to the needs of every application
- Existing radio stack architectures are monolithic in nature, combining core functionality with power management
  - ⇨ Hard to develop new protocols or tune existing ones to specific application requirements

Solution: (UPMA)

- *Unified Radio Power Management Architecture*
- Movement away from purely monolithic radio stack architecture
- Enables pluggable power management policies based on differing application demands
- Requires separation of “core” radio functionality from power management features
- Cross layer in nature, supporting coordination between different policies existing at each layer
- Consists of both low-level programming interfaces as well as high-level modeling abstractions

Outline

- Radio power management overview
- Design of UPMA
    - Low level architectural abstractions
    - High level modeling abstractions
- Configuration and analysis tools
- Open issues

Radio Power Management

- Major Categories
  - Power Aware Routing
  - Topology Control
  - Duty Cycling
- Duty Cycling Approaches
  - TDMA (e.g 802.15.4)
  - Scheduled Contention (e.g. S-MAC)
  - Channel Polling (e.g. B-MAC)
  - Hybrid (e.g. SCP)
- Complementary Protocols
  - Backbone (e.g SPAN)

Protocol Comparison

- TDMA Protocols
  - Reduce contention
  - Time synchronization overhead
  - Sensitive to changes in network topology / traffic patterns
- Scheduled Contention Protocols
  - Low sending cost
  - High reception cost
  - Time synchronization overhead
- Channel Polling Protocols
  - High sending cost
  - Low reception cost
  - NO time synchronization required

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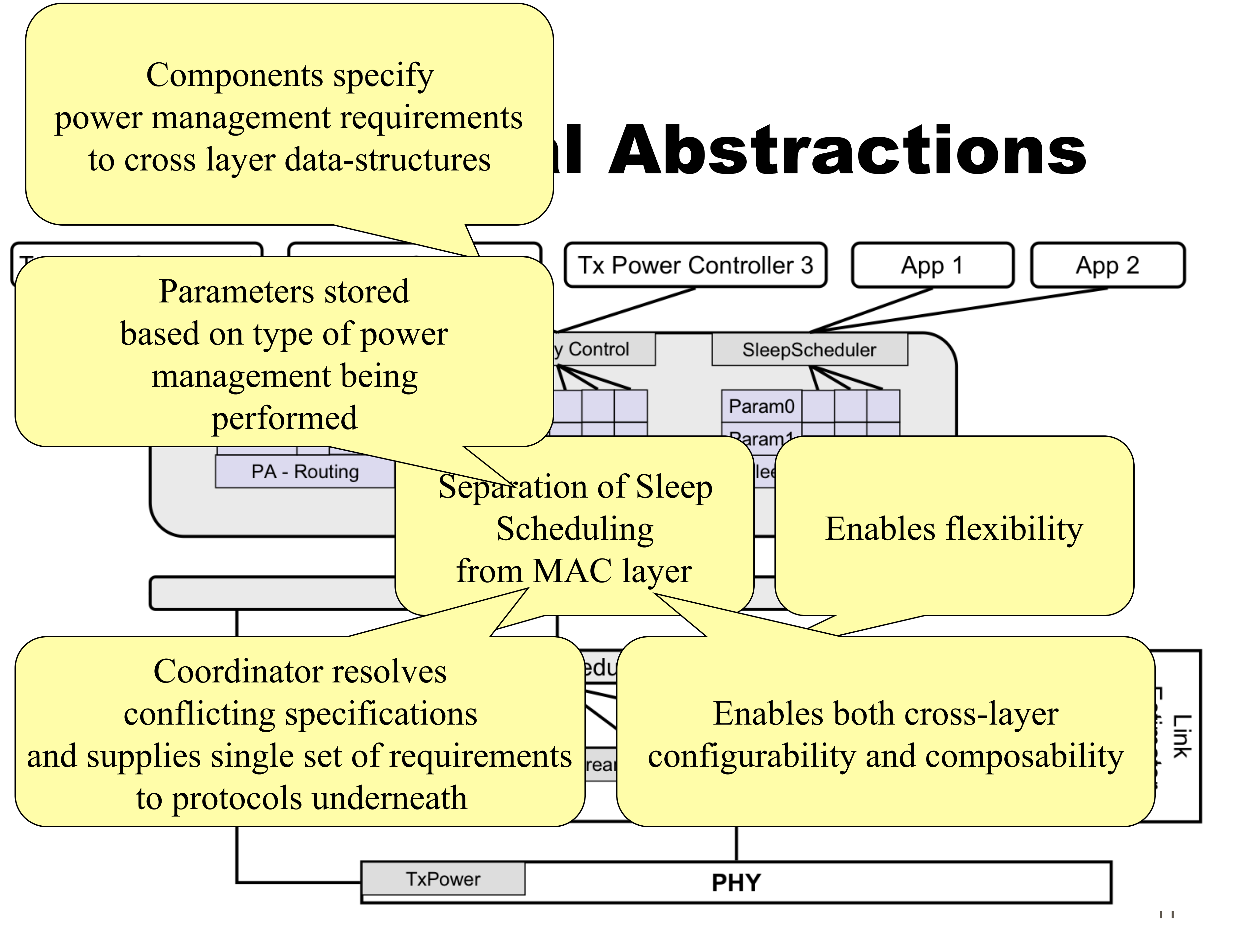
Goals of UPMA

- Support flexibility
  - Allow different power management protocols to be chosen based on varying application requirements
- Support cross layer configuration
  - Allow protocols to be optimally configured across layers rather than at a single layer alone
- Support composability
  - Allow multiple protocols at various layers to be composed together without modification (code reuse)

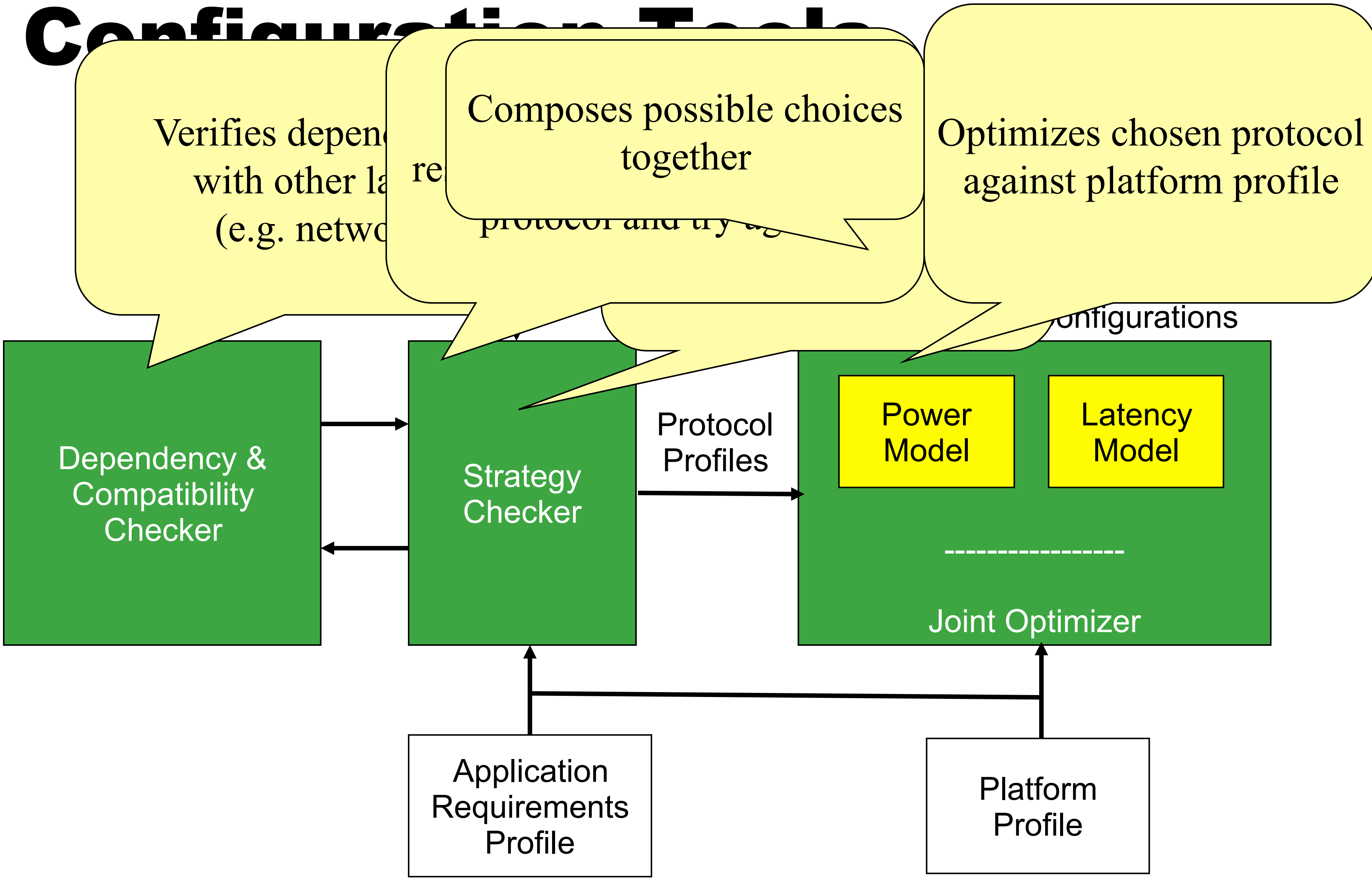
Current implementation in place for supporting flexibility and composability at the Data Link Layer


l Abstractions
Components specify
power management requirements
to cross layer data-structures
Tx Power Controller 3
App 1
App 2
Parameters stored
based on type of power
management being
performed
y Control
SleepScheduler
Param0
Param1
PA - Routing
Separation of Sleep
Scheduling
from MAC layer
Enables flexibility
Coordinator resolves
conflicting specifications
and supplies single set of requirements
to protocols underneath
Enables both cross-layer
configurability and composability
Link
TxPower
PHY

Modeling Abstractions

- Profiles specifying key characteristics of:
  - Power management protocols
  - Networking protocols
  - Hardware platforms
  - Applications
- Used for resolving interdependencies among them
- e.g. Which PM protocol should I use with MINT route for a habitat monitoring application with maximum XXms delivery latency and 1% duty cycle?

Configuration Tools



Open Issues

- Cross-layer coordination policies
  - Not clear when to update data in power tables for performing coordination
  - If so, when should these hooks be triggered?
  - Should upper layer components always supply requirements or should they be requested through hooks?
  - Are we capable of producing a unified one-size-fits-all coordination policy?

Open Issues

- Design of modeling abstractions
  - Must be scalable as new applications, platforms, and protocols continue to emerge
  - Support for heterogeneous networks
  - Possible Solution: *Hierarchy of system attributes*

Open Issues

- Joint optimization of composable power management protocols
  - Modeling and optimizing several protocols simultaneously is difficult
  - Requires systematic approach
  - Possible Solution: *Power Management Patterns*

Summary

- Different applications have different requirements
  - Throughput
  - Latency
  - Network lifetime
- Various power management protocols designed to meet these needs differently
- UPMA designed to allow:
  - Flexible integration of radio power management protocols
  - Cross-layer configuration of multiple protocols
  - Composability of complementary protocols
- Open Issues currently under investigation

Questions?