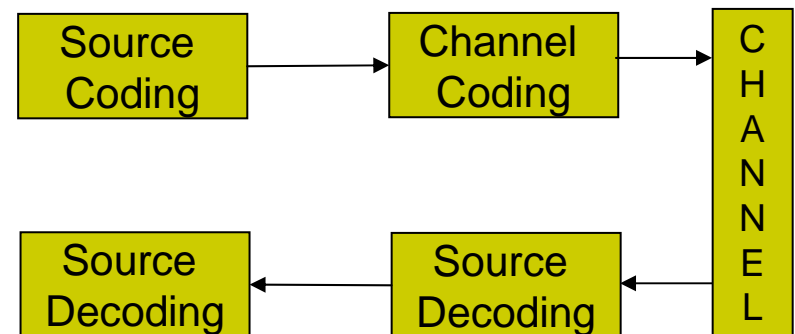
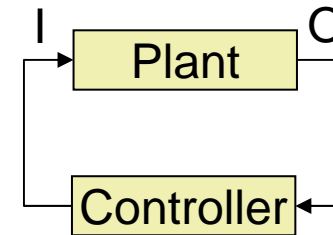
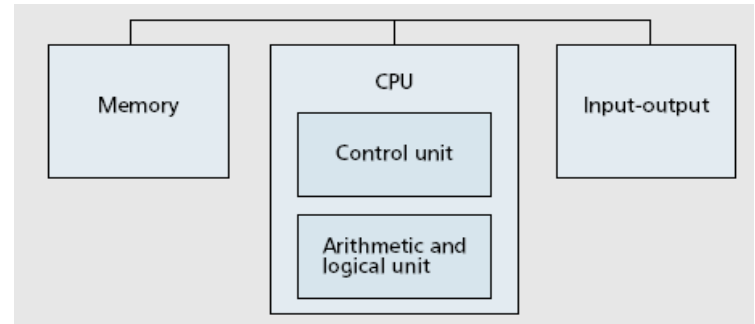


# Some issues in Cross-Layer Architecture in Mobile Ad Hoc Networks

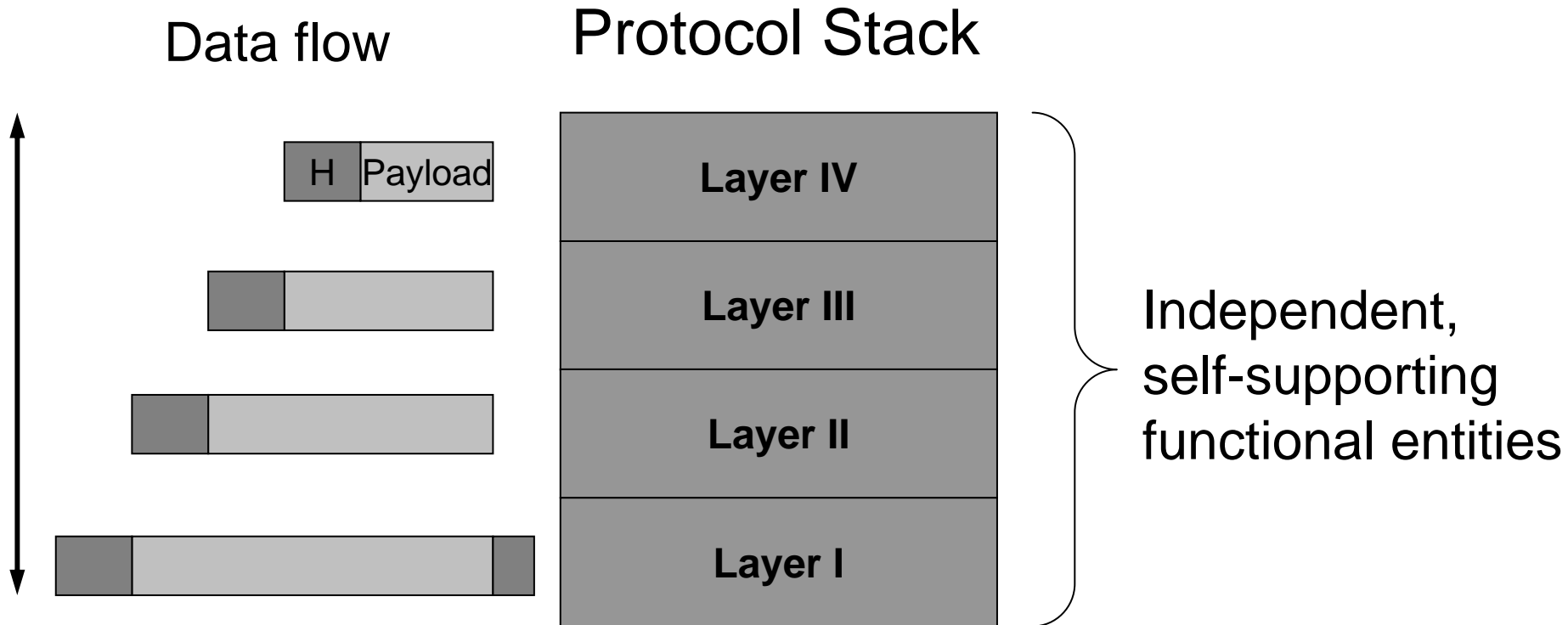
Navid Nikaein and Rolf Winter  
Institut Eurecom  
Freie Universität Berlin  
<http://manet.eurecom.fr>

# Importance of a Good Architectural Design

- The Von Neumann Architecture
  - Separation between software and hardware (Bridge)
- Feedback Control System
  - Separation between plant and controller
- The Shannon Digital Communication System Architecture
  - Separation between source coding and channel coding



# Layered Network Architecture (OSI)



Layer triggers is used to notify events between layers in this architecture  
For instance, congestion notification triggers by IP layer to TCP

# Advantages, But ...

- Low complexity
- Modular and upgradeable (low maintenance)
  - Longevity → proliferation, and thereby cost-effective
  - Allow to construct network stack tailored towards different network environments
- Easy to standardize
  - Due to inter-layer interoperability and peer-to-peer principles
- However, the underlying assumptions are:
  - Each layer can be optimized independently
  - This assumption turns out to be not true in dynamic environments
    - Channel quality changes
    - Routing changes
    - QoS requirements changes
- Alternative solution is cross layer architecture

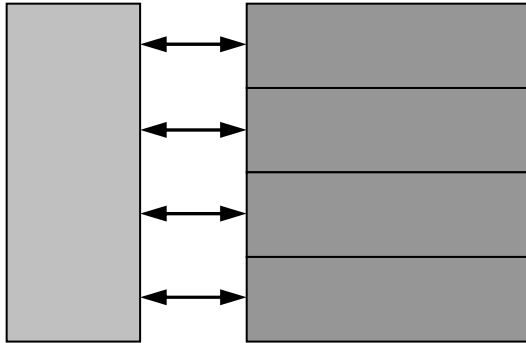


# Concept of Cross-Layering

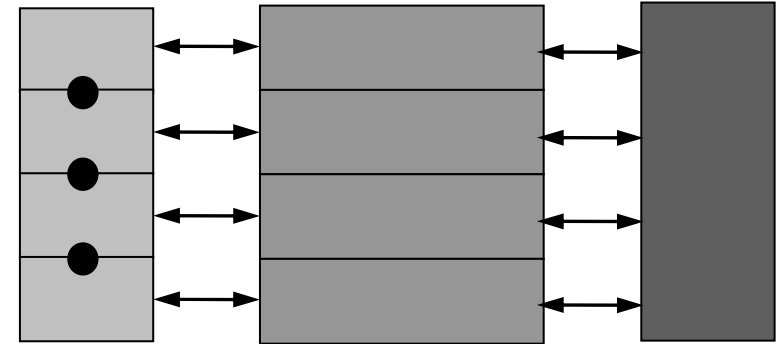
- Not a replacement of a layered architecture
- Not a combination of a layered functionalities
- It is about sharing the information amongst different layers for adaptations
- However, this process has to be coordinated to
  - Avoid unintended or unnecessary consequence
  - Control process dependency relationship
  - Enforce timescale separation between different process
  - Establish stability due to loop formation
- For instance, optimization processes at different layers could go in opposite directions
  - Power control and routing
  - Energy efficiency and delay performance

# Cross Layer Architectures

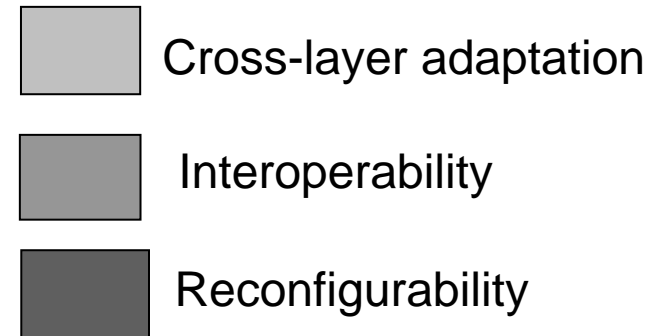
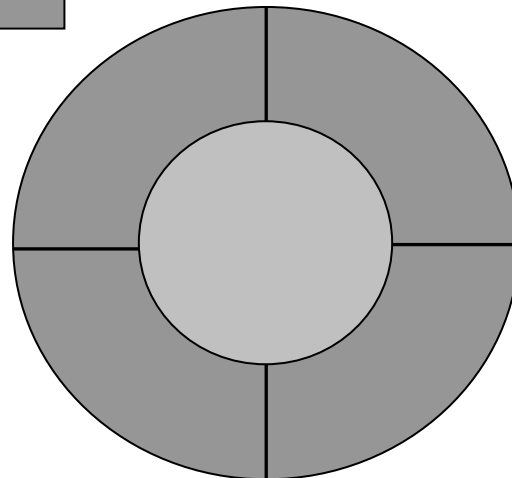
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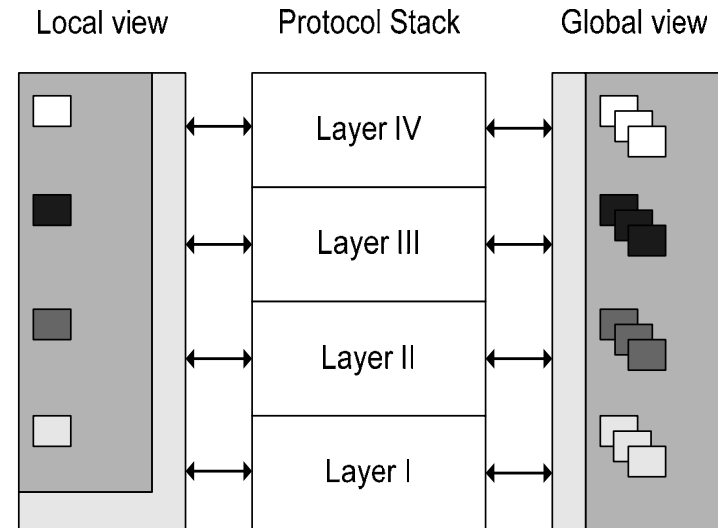
GRACE



**These architectures provide protocol optimization w.r.t. local state information**

# Cross Layer Architectures

- Local actions are lightweight but they lack accuracy and ultimately efficiency
- Network-wide, global actions are expensive but often not avoidable
- CrossTalk bases local actions on global knowledge to achieve global objectives



CrossTalk[winter05]

# Cross Layer Architectures

- Think globally, act locally [streenstrup]
  - Requires network cooperation
  - Local action requires global knowledge
  - Beware of their different timescales to maintain stability
  - Global knowledge must be determined as a function of network condition
  - Such global knowledge is then feedbacked to local decisions iteratively



# Cross-Layer Design: Pros & Cons

- Exploit the inter-layer interactions
- Adaptability across layers through exchanged information
  - If the local adaptation is not sufficient, state information are cross-layered to other layer for more specific or general response
- Protocol optimization
  - Depends on the system constraint !
- Joint optimization across layers lead to more complex algorithm
  - Difficult to characterize
- May cause unnecessary optimization affecting the regular functionality of the layer whose functionality was insufficient
- May cause loops
  - Spaghetti like design

# Comparison

	<b>Layered</b>	<b>Cross-Layer</b>
<b>Advantages</b>	Reduced design complexity	Various ways to improve adaptability & performance
	Improved maintainability	
	Modularity	
<b>Disadvantage</b>	Leaves out certain performance & adaptability improvements	Cautious design is necessary
<b>Preferable</b>	Large & Reliable Networks	Wireless Mobile Networks

# To Layer or Not to Layer?

- In a dynamic environment, should we keep a layered network architecture or instead all layers have to be integrated and jointly optimized ?
  - Fully integrated approach is impractical
    - In terms of implementation, debugging, upgrading, and standardization
  - Hence, keep the layer approach for mainlining the interoperability, while taking into account the cross-layering for joint optimization
- Questions:
  - What is the appropriate cross-layer architectures?
  - What information should be exchanged across layers?
  - How should that information be used for adaptation ?
  - Note: Trade-off between performance and architecture

# Cross Layer Adaptations

- Physical Layer
    - Channel state and BER
  - MAC Layer
    - Link quality
    - Neighborhood info
    - Battery level
  - Network Layer
    - Network topology
    - Traffic volume
    - QoS requirements
  - Transport Layer
    - Packet loss rate
  - Application Layer
    - Scenarios parameters
    - User capacity
    - System Constraints
- Physical Layer
    - Coding and modulation
  - MAC Layer
    - Retransmission policy
    - fragmentation
    - Scheduling (incl. coding rate)
    - Power control
  - Network Layer
    - Routing policy
    - Switching interface (channel)
  - Transport Layer
    - Congestion window size
  - Application Layer
    - Rate adaptation

# Reconfigurability w.r.t. the Network Constraints

- How should global system constraints and characteristics be factored into protocol functionalities at each layer?
  - Need for Reconfigurability

# Conclusion

- Interoperability, cross-layering and reconfigurability are three important concepts of today's systems
- Cross-layering is a key design choice for improving network performance in dynamic environments
- Some cautionary perspectives must be taken into account
  - Setting the context of cross-layer optimization