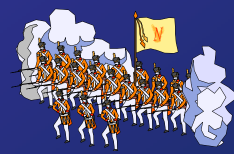
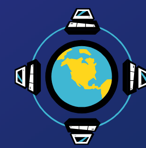
# §6 Resource Management

- Goals:
  - scalability
  - performance

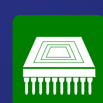




- Methods:
  1. Optimizing the communication protocol
     - packet compression and aggregation
  2. Controlling the visibility of data
     - area-of-interest filtering
  3. Exploiting perceptual limitations
     - altering visual and temporal perceptions
  4. Enhancing the system architecture

# Information-Centric View of Resources

- Bandwidth requirements increase with the number of users
- Each additional user
  - must receive the initial NVE state and the updates that other users are already receiving
  - introduces new updates to the existing shared state and new interactions with the existing users
  - introduces new shared state



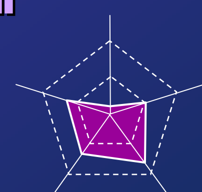
- Additional users require additional processor cycles at the existing user's host
- Each additional user
  - introduces new elements to render
  - increases the amount of caching (new shared state )
  - increases the number of updates to receive and handle

## Networked Virtual Environment Information Principle

*The resource utilization of an NVE is directly related to the amount of information that must be sent and received by each host and how quickly that information must be delivered by the network.*

- The most scalable NVE is the one that does not require networking
- To achieve scalability and performance, the overall resource penalty incurred within an NVE must be reduced

## Information Principle Equation



Resources = $M \times H \times B \times T \times P$

$M$ = number of messages transmitted

$H$ = average number of destination hosts for each message

$B$ = average amount of network bandwidth required for a message to each destination

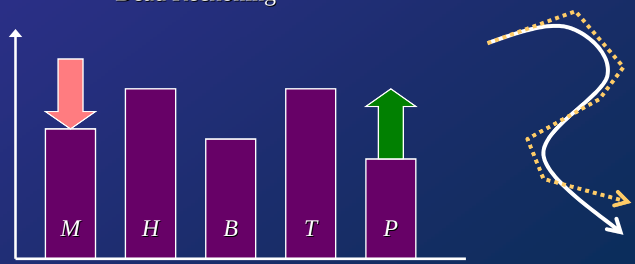
$T$ = timeliness in which the network must deliver packets to each destination

$P$ = number of processor cycles required to receive and process each message

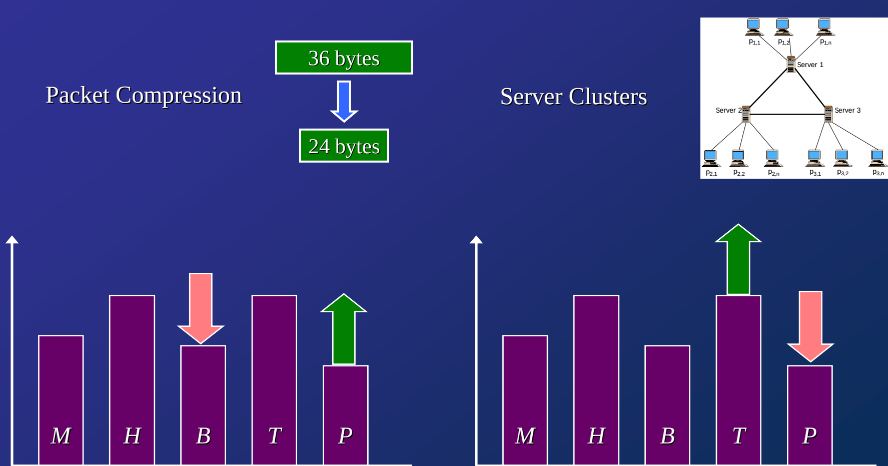
# Information Principle Equation as a Tool

- Each reduction ⇒ a compensating increase or a compensating degradation in the quality
- How to modify depends on the application

Dead Reckoning

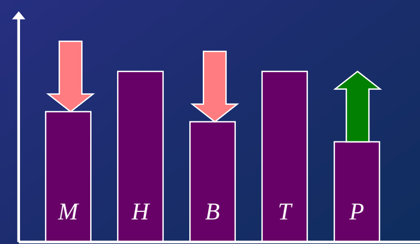



# Information Principle Equation: Examples



## §6.1 Optimizing the Communication Protocol

- To transmit data
  - allocate a buffer
  - write data into the buffer
  - transmit a packet containing the buffer contents
- Every network packet incurs a processing penalty
- To improve resource usage, reduce
  - the size of each network packet (packet compression)
  - the number of network packets (packet aggregation)




## Optimizing the Communication Protocol (cont'd)

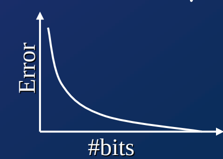
- Packet compression
- Protocol independent compression algorithm (PICA)
- Localized compression using application gateways

- Packet aggregation
- Aggregation trade-offs and strategies
- Aggregation servers

## Packet Compression

*Lossless* compression
- Change encoding
- No information loss
  - 10.0000001 ⇒ 10.0000001

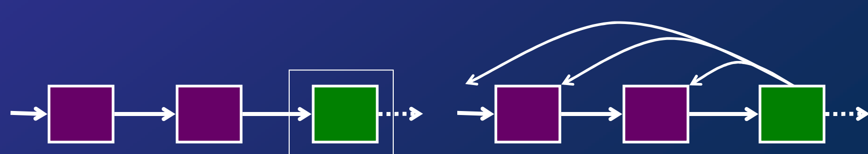
*Lossy* compression
- Some information may be lost
  - 10.000000001 ⇒ 10




## Internal and External Compression

*Internal* compression
- Manipulates a packet based solely on its own content
- No reference to the previous packets

*External* compression
- Manipulates the packet data within the context of what has already been transmitted
  - delta information
- Better compression
- Dependency between packets
- Need for reliable transmission

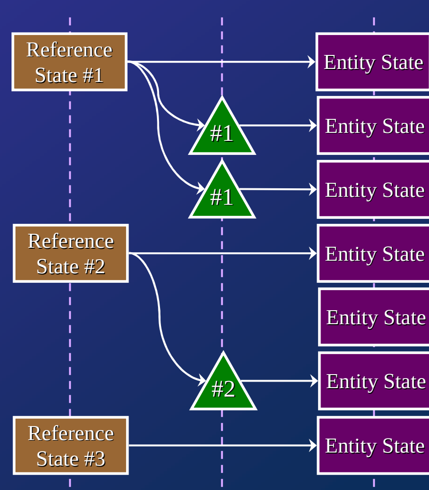


## Compression Technique Categories

| Compression technique | *Lossless compression* | *Lossy compression* |
|---|---|---|
| *Internal compression* | Encode the packet in a more efficient format and eliminate redundancy within the packet | Filter irrelevant information or reduce the detail of the transmitted information |
| *External compression* | Avoid retransmitting information that is identical to that sent in previous packets | Avoid retransmitting information that is similar to that sent in previous packets |

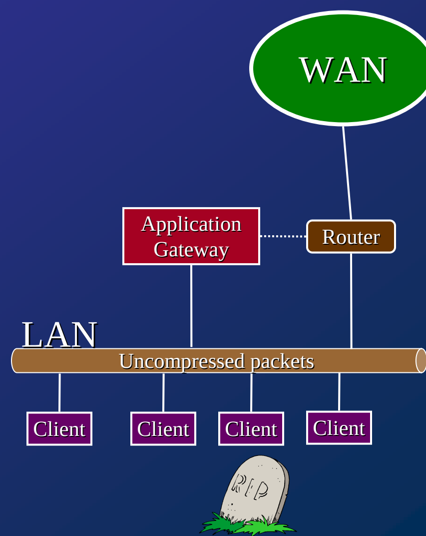
## Protocol Independent Compression Algorithm (PICA)

- Lossless, external
- Transmit occasionally numbered reference state snapshots
- Subsequent update packets
  - snapshot number
  - delta information
- Snapshots reliably
  - easy retransmission



# Application Gateways

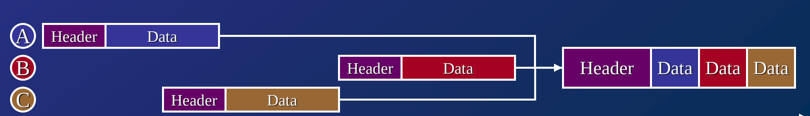
- Compression can be localized to areas of the network having limited bandwidth
- Packet in uncompressed form over the LAN
- Application Gateway (AG) compress them before they enter the WAN
- Quiescent entity service
  - handles dead or inactive entities




# Packet Aggregation

- Reduce the number of packets by merging multiple packets
- Reduces the number of packet headers
  - UDP/IP: 28 bytes
  - TCP/IP: 40 bytes


- Merge all packets of the local entities into a single packet
  - suits when packets are transmitted at a regular frequency
  - does not decrease the quality
  - if each entity generates updates independently, the host must wait to get enough packets

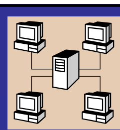


## Aggregation Trade-offs and Strategies

- Wait longer
  - better potential bandwidth savings
  - reduces the value of data
- Timeout-based transmission policy
  - collect packets for a fixed timeout period
  - guarantees an upper bound for delay
  - reduction varies depending on the entities
    - no entity updates ⇒ no aggregation but transmission delay
- Quorum-based transmission policy
  - merge packets until there is enough
  - guarantees a particular bandwidth and packet rate reduction
  - no limitation on delay
- Timeliness (timeout) vs. bandwidth reduction (quorum)

## Merging Timeout- and Quorum-Based Policies

- Wait until enough packets or timeout expired
- After transmission of an aggregated packet, reset timeout and packet counter
- Adapts to the dynamic entity update rates
  - slow update rate ⇒ timeout bounds the delay
  - rapid update rate ⇒ better aggregation, bandwidth reduction



# Aggregation Servers

- In many applications, each host only manages a single entity
- More available updates, larger aggregation packets can be quickly generated
- Large update pool ⇒ projection aggregation
  - a set of entities having a common characteristic
    - location, entity type
- Aggregation server
  - hosts transmit updates to aggregation server(s)
  - server collects updates from multiple hosts
  - server disseminates aggregated update packets
- Distributes the workload across several processors
- Improves fault tolerance and overall performance