# On Coherence Intervals and the Control Paradox

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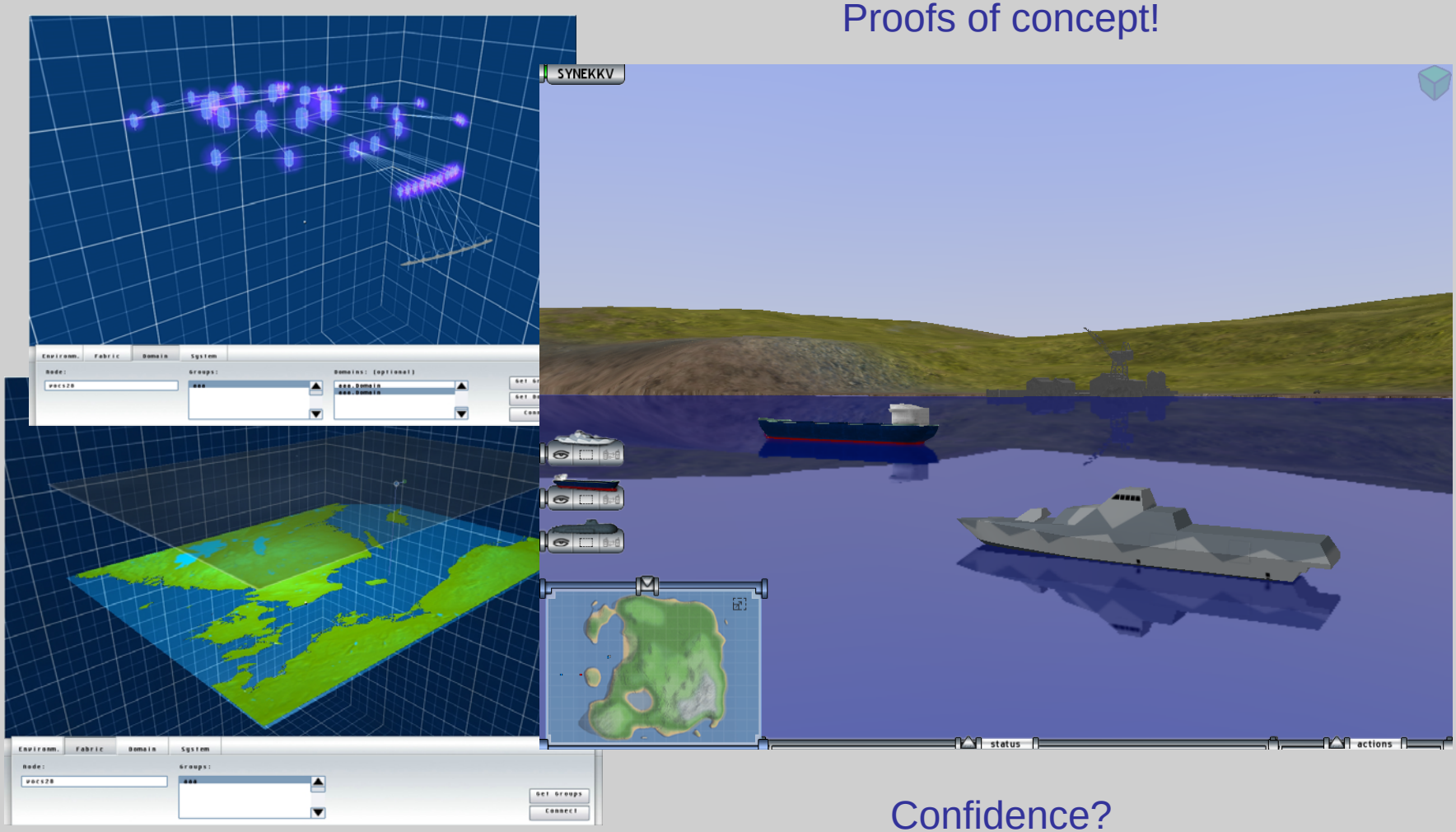
# Introduction

- Distributed systems
  - Nodes are related so with respect to each other, that communication takes a significant amount of time
  - Nodes take inputs from their local envirionments
- Cognitive capabilities
  - Assume internal, ”sensemaking” processess at the nodes
- Temporal models
  - Absolute time. Normalized time.
  - Duration of events. Interval between events

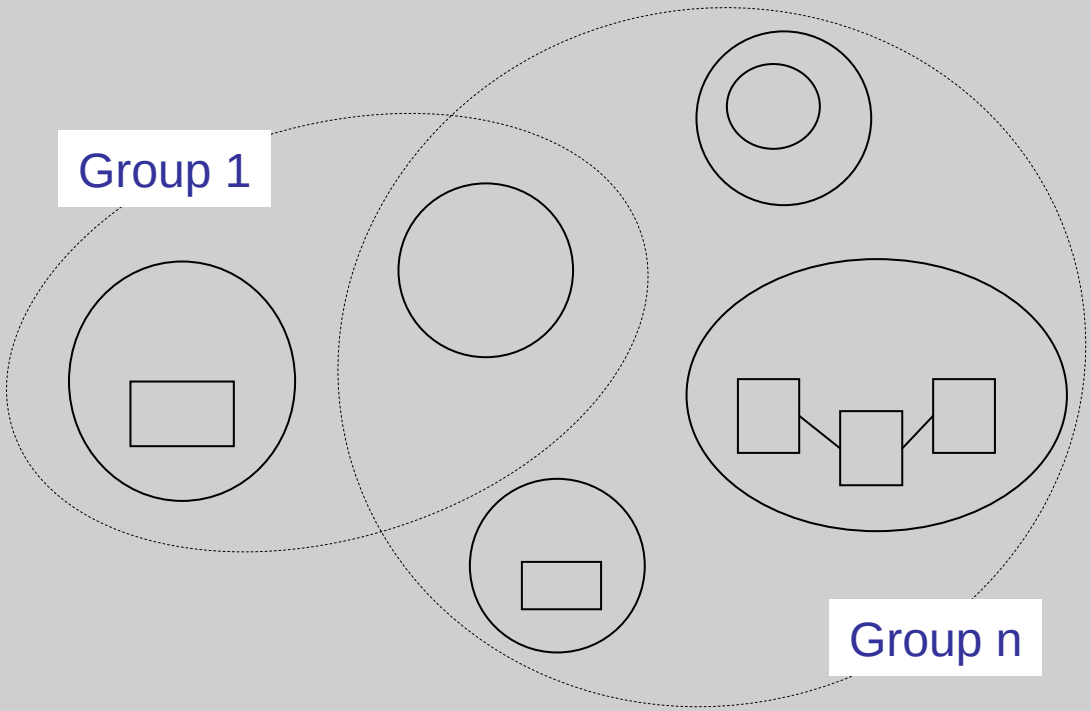
# Background – Simulation-based demonstrators

Proofs of concept!

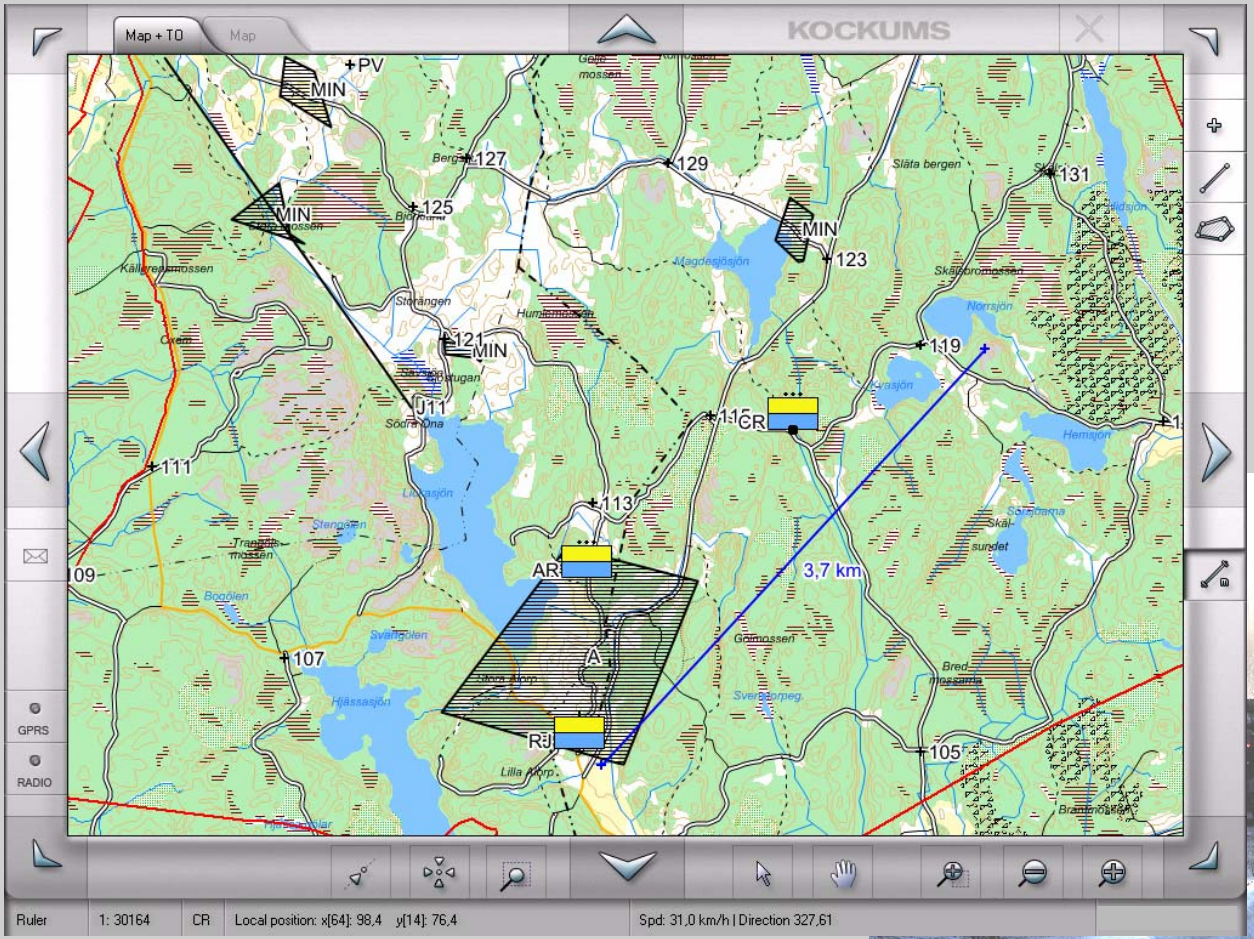



Confidence?

# Background – Peer-based group-think

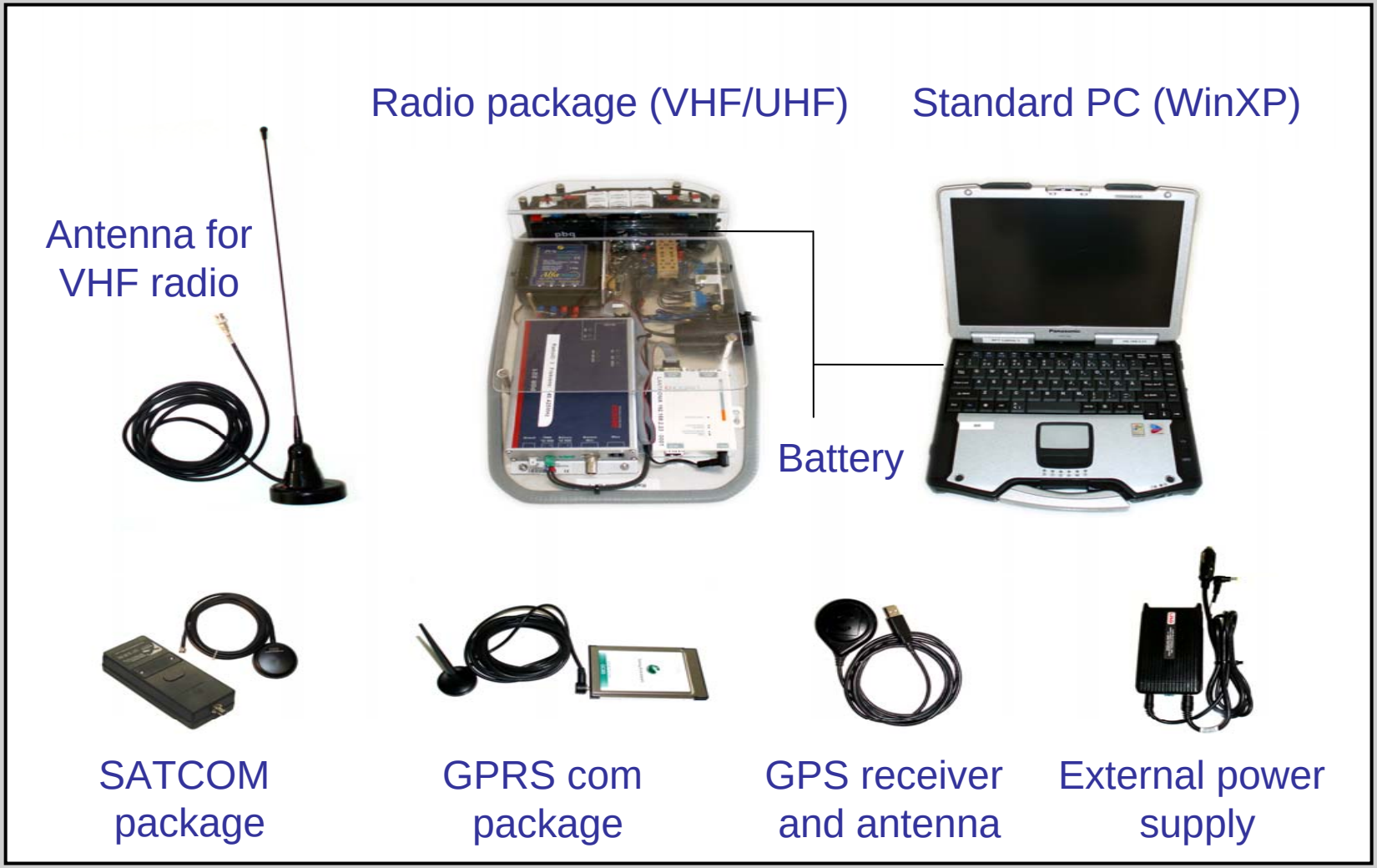


# Background – The Distributed Blue Force Tracker (DBFT)

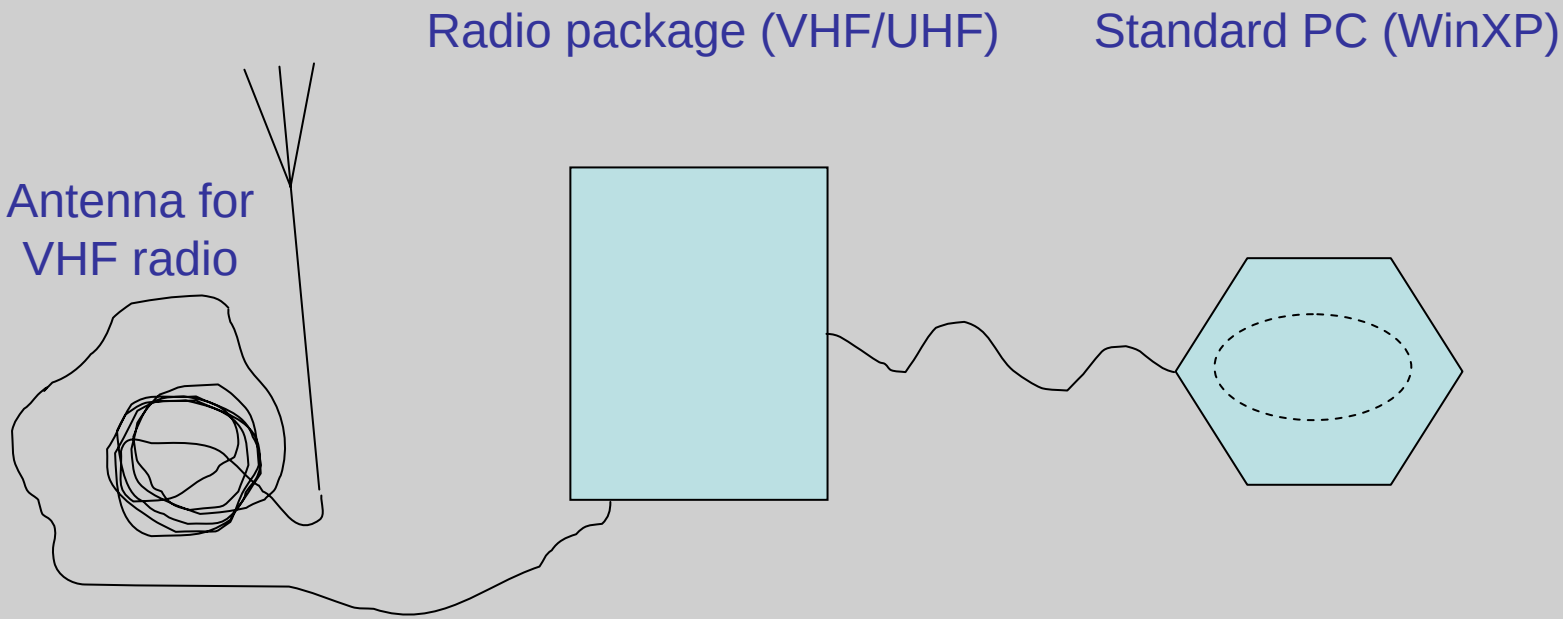



Field tests with real nodes in army training organisation

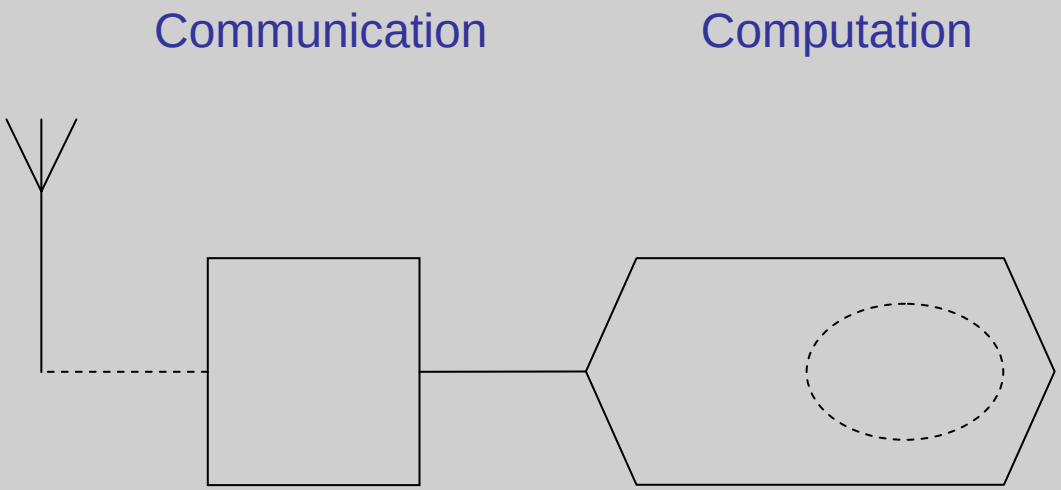
# Background – DBFT hardware view



# Background – DBFT schematic view

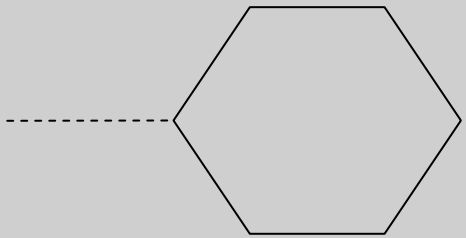


# Background – DBFT schematic view 2

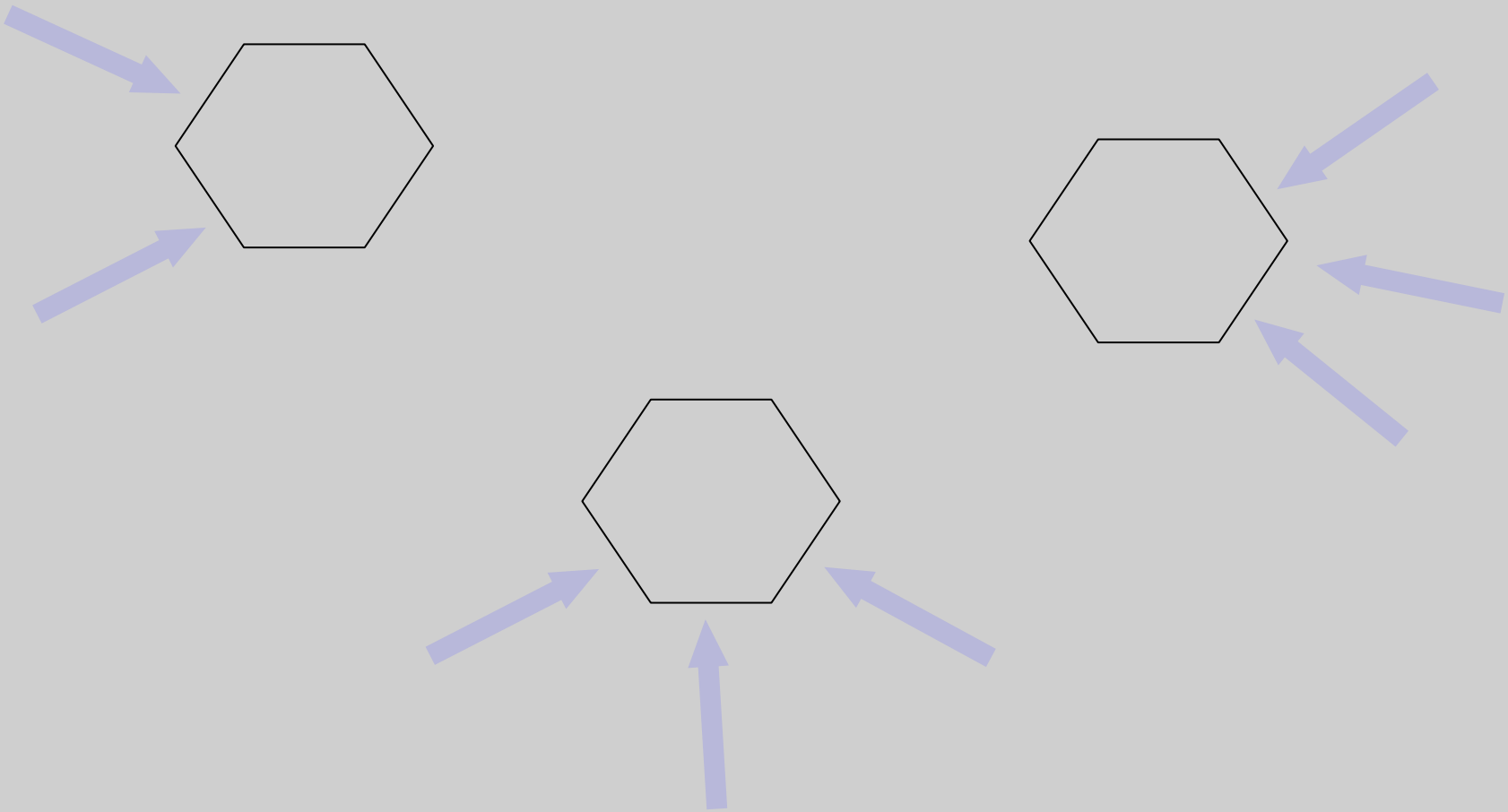


# Background – DBFT schematic view 3

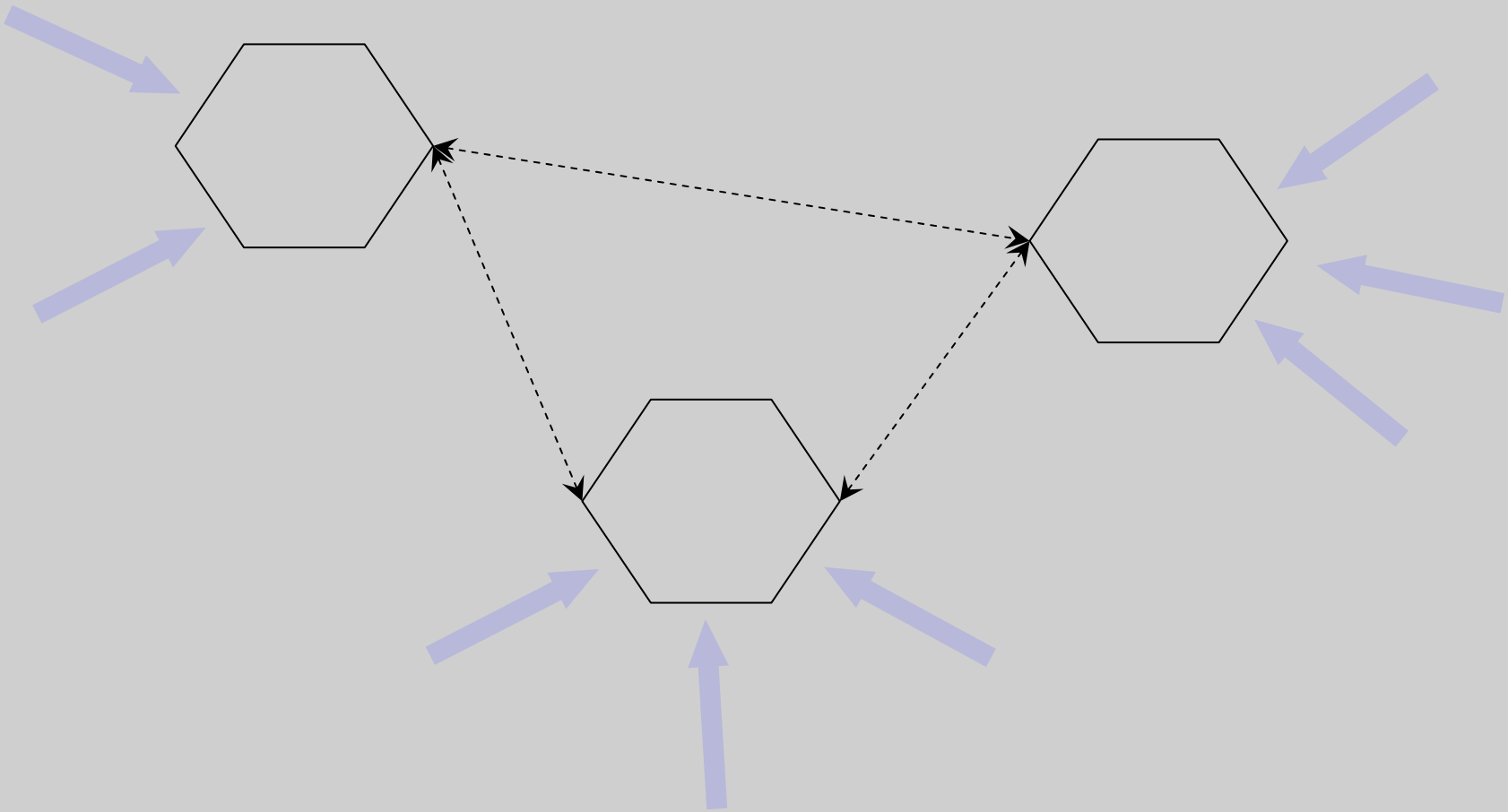
Node



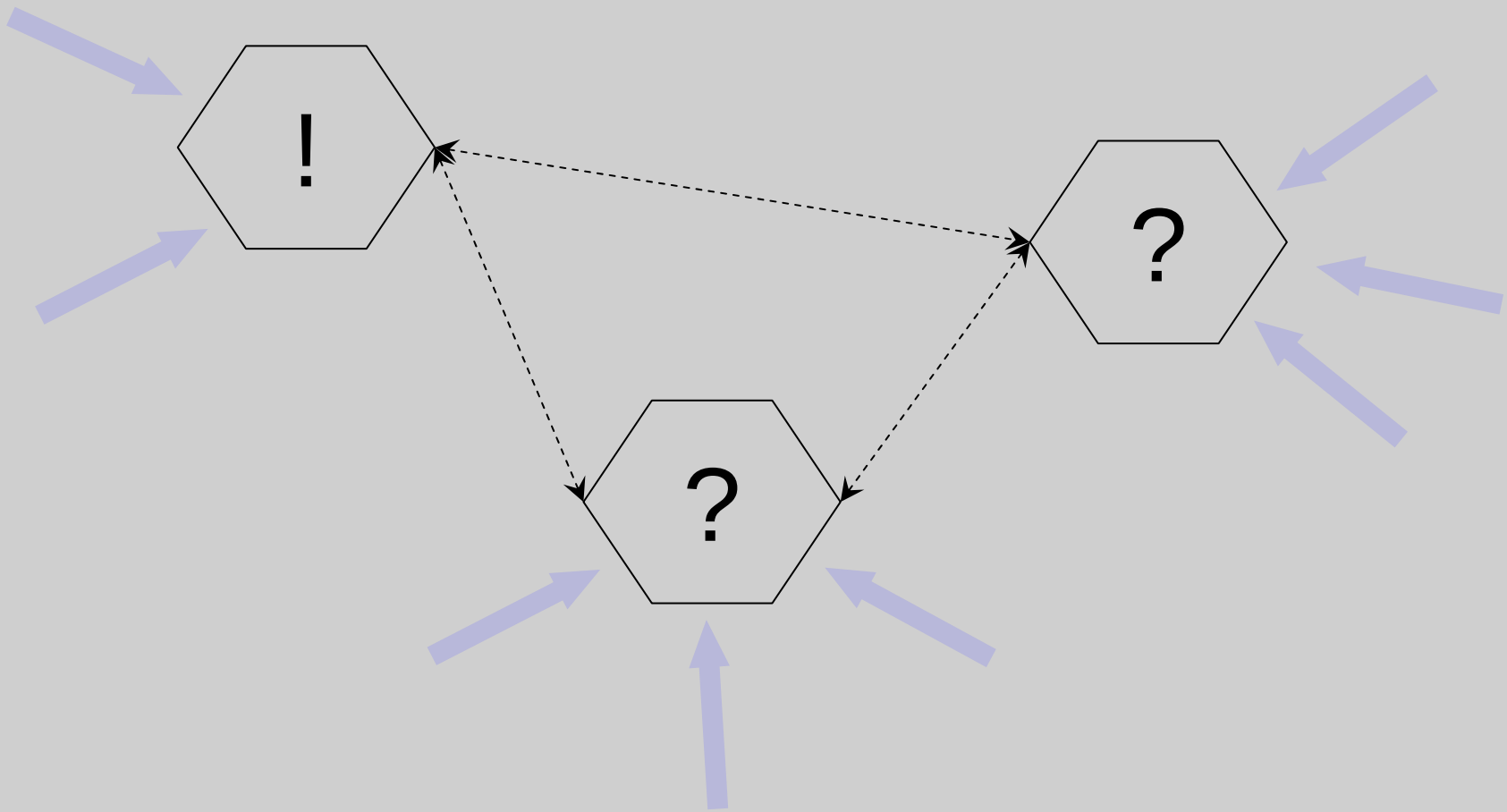
# All nodes take input from their respective environments



# All nodes send messages to all other nodes



# All nodes are (more or less) out of pace!



## Application problem

- Demonstrators with simulated nodes sometimes show unexpected behaviours
- Demonstrators with real nodes sometimes become irresponsive (and we are comparatively tolerant for the unexpected)

- Unexpected behaviours indicates loss of control (which is bad)
- Irresponsive systems indicates loss of control (wich still is bad)

- Observation: Timing adjustments seem to be part of all fixes
- Also, irresponsiveness make data irrelevant – too old to be useful

=> Let's investigate under what circumstances nodes in real, distributed systems *actually* has access to the same – *coherent* – set of data

## Coherence

Assumption: Coherent data is a prerequisite for ”shared awareness”

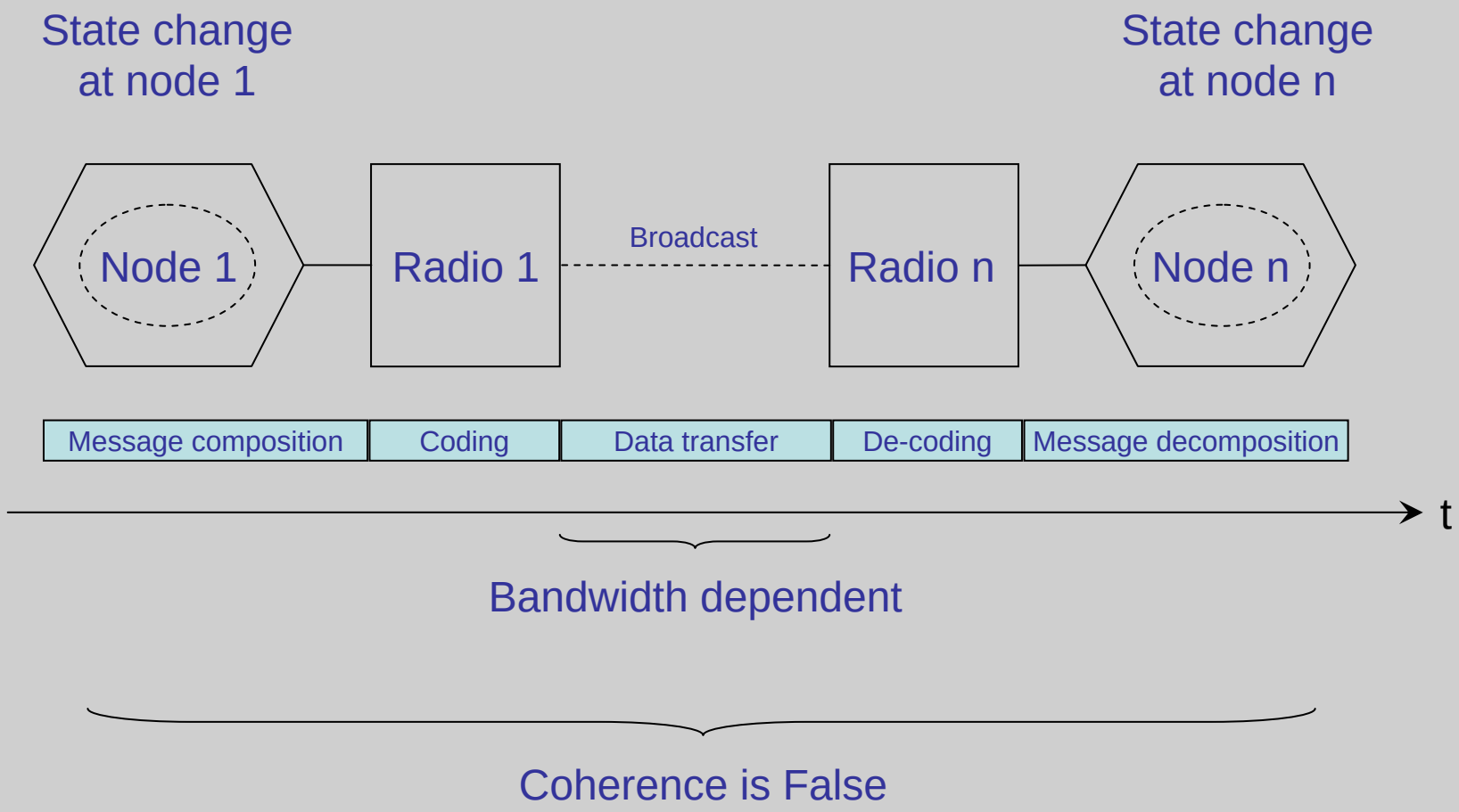
A group has a coherent set of data,
when all nodes/members assign the same value
to a shared attribute

So, first there has to be a group which has a set of common attributes, and the intention of maintaining a common set of corresponding values

Coherence is lost (False) whenever one such value is changed at any of the nodes in the group, unrecognised by the others

Coherence is regained when that change has been communicated to all other nodes, so the respective corresponding attribute is updated

# Nodes – Communication model



## Measurement problem

We want to investigate data coherence:

Every node takes sensory data and messages as input

Every node sends messages with some interval

Every message takes some time to come through

Practical problem:

When we want to measure the messages

and every measurement is a message

the measurements affects the measured.

Heisenberg uncertainty

1. Make use of local databases
2. Do some post operations number-crunching
3. Try to make sense of the results

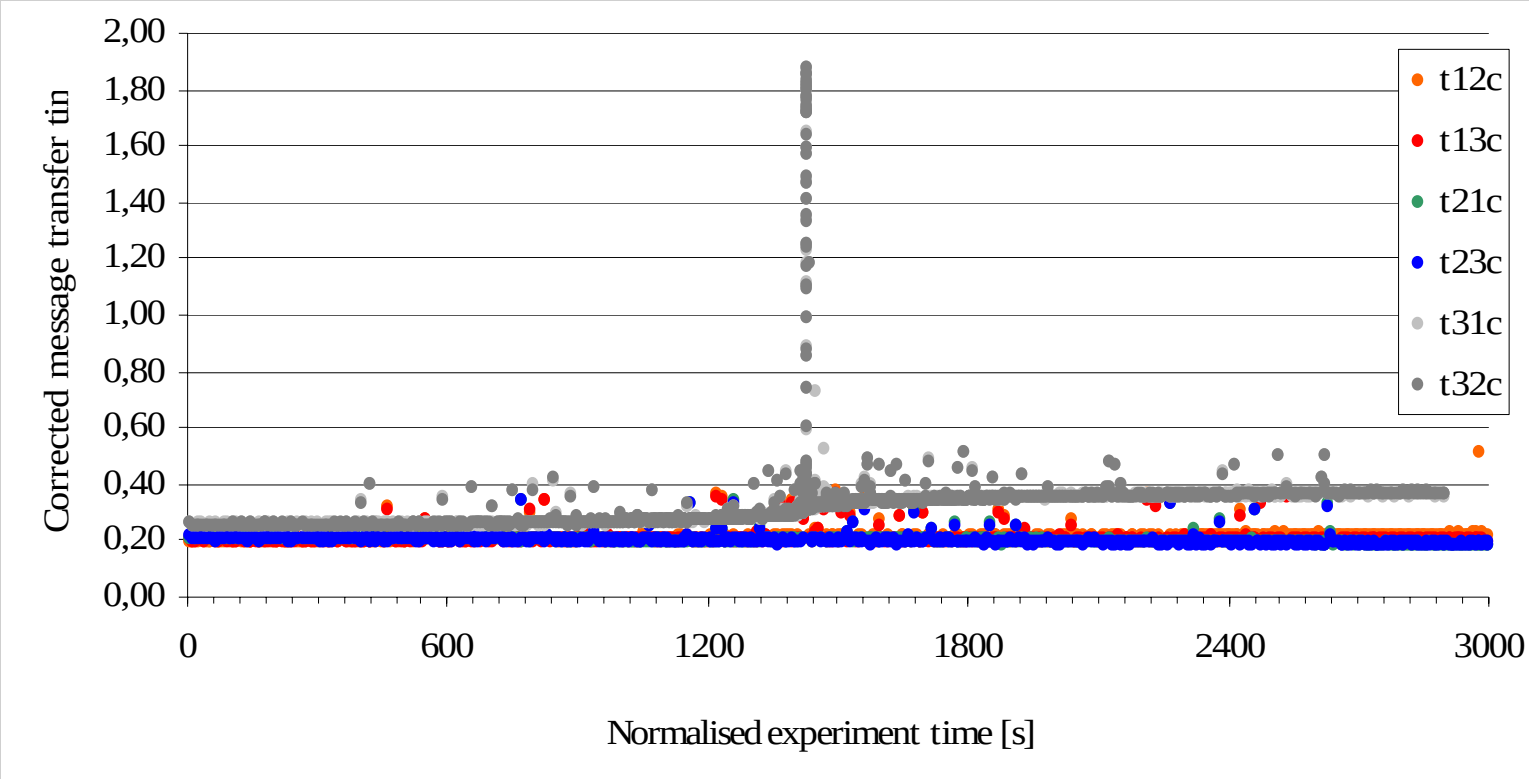
## Experiments

- General setting
  - Three nodes with minimal computational load
  - Computers, VHF radio 9600 baud, 100 byte messages
  - Nominal message transfer time about 0.083 s
  - Temporal corrections and coherence fractions are calculated after completed experimental runs

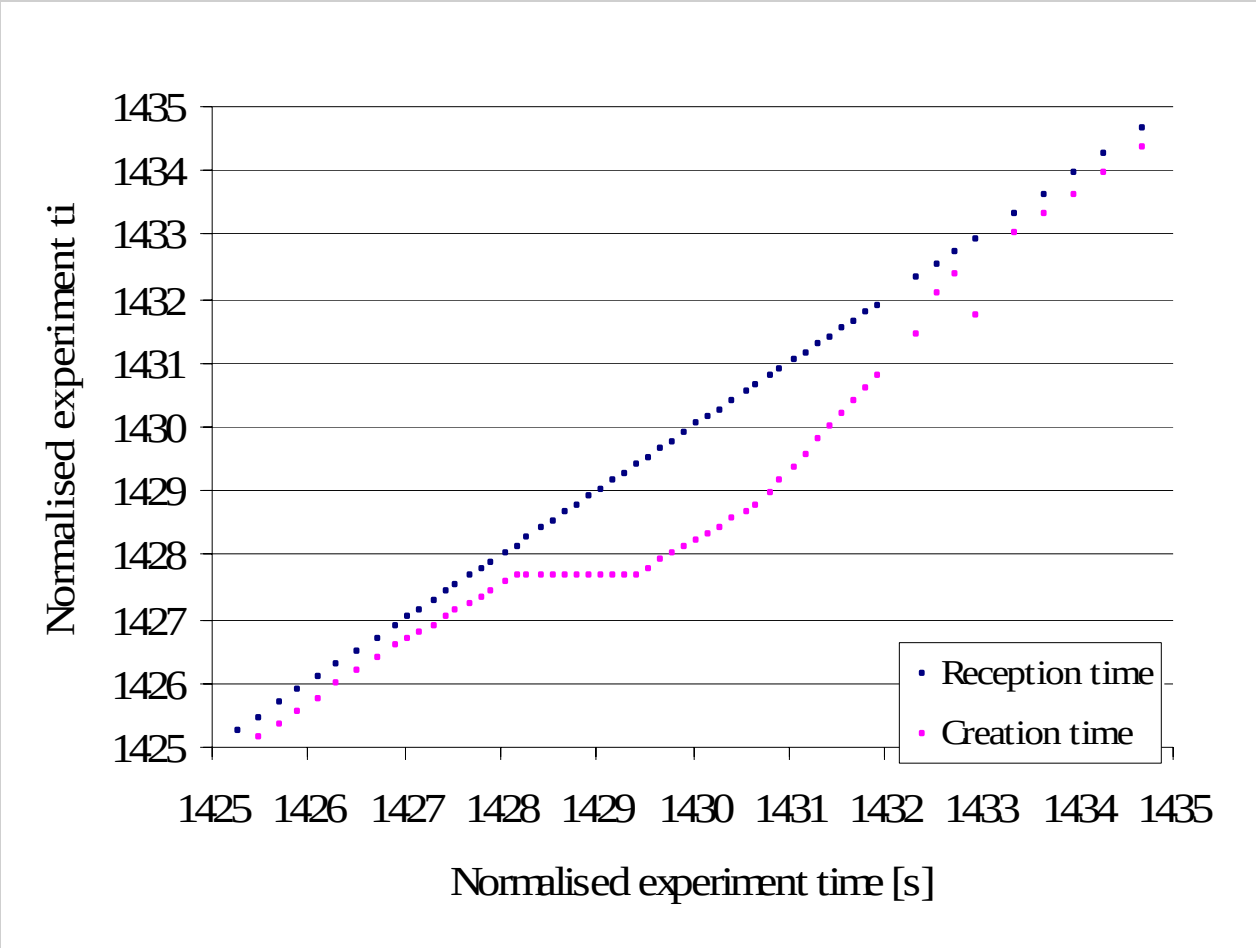
- Experiment 1
  - All three nodes send message at interval 5 seconds
  - Actual message time about 0.20 – 0.25 s
  - Spontaneous decrease of coherence due to race conditions

- Experiment 2
  - One node decrease interval between messages from 5 to nominal 0 seconds and then increase interval again.

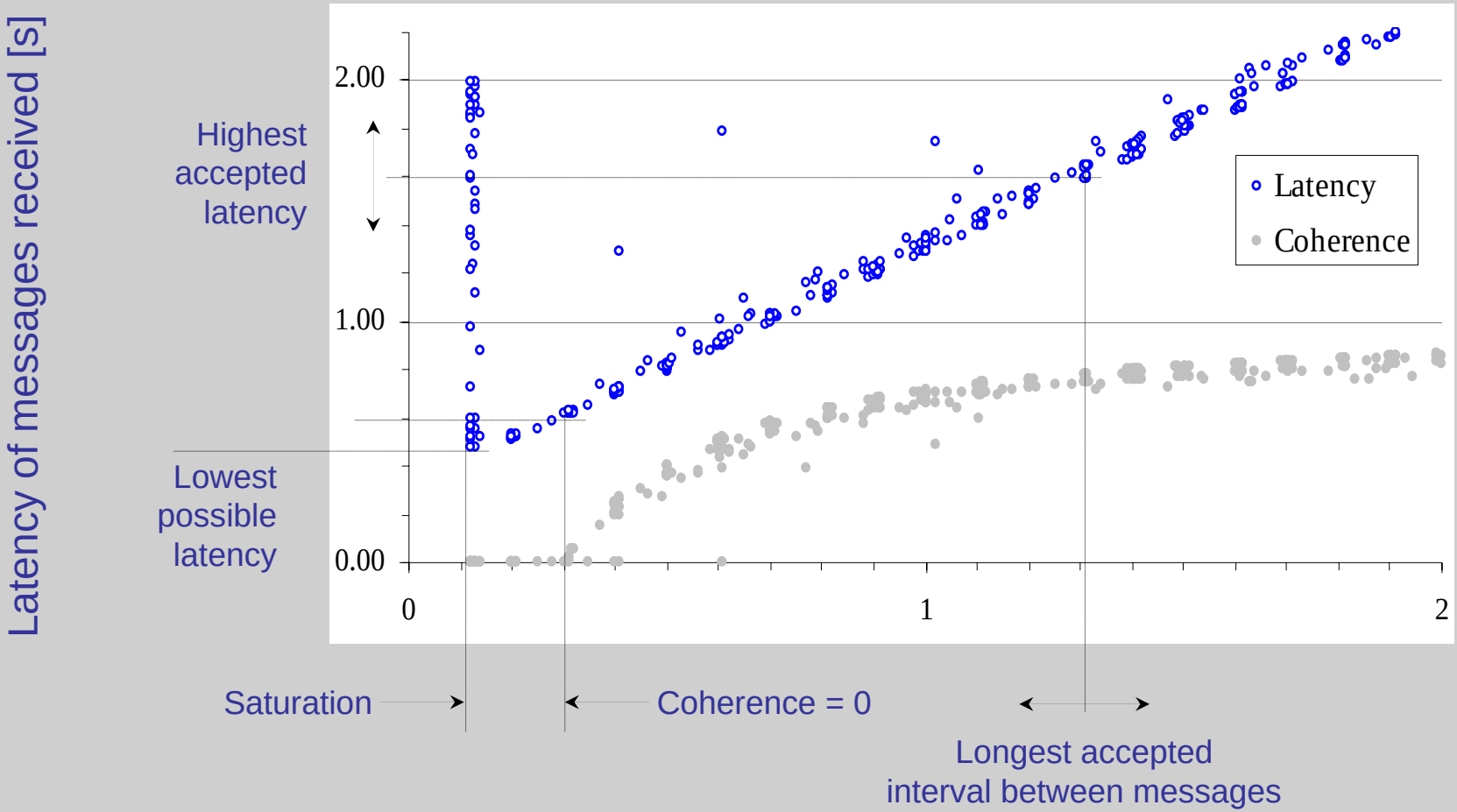
# Experiment 2 – Message delivery time; sending node perspective



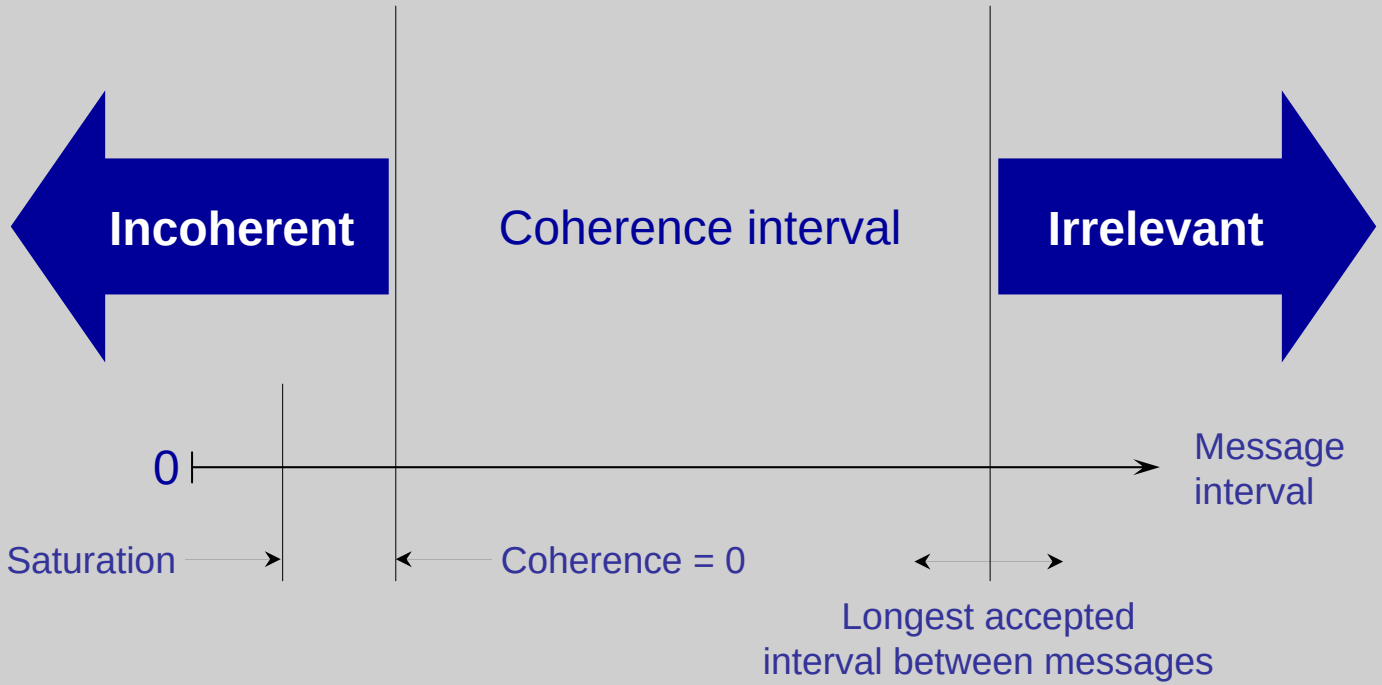
# Experiment 2 – Message age at arrival; receiveing nodes perspective



# Interpretation – data latency and coherence



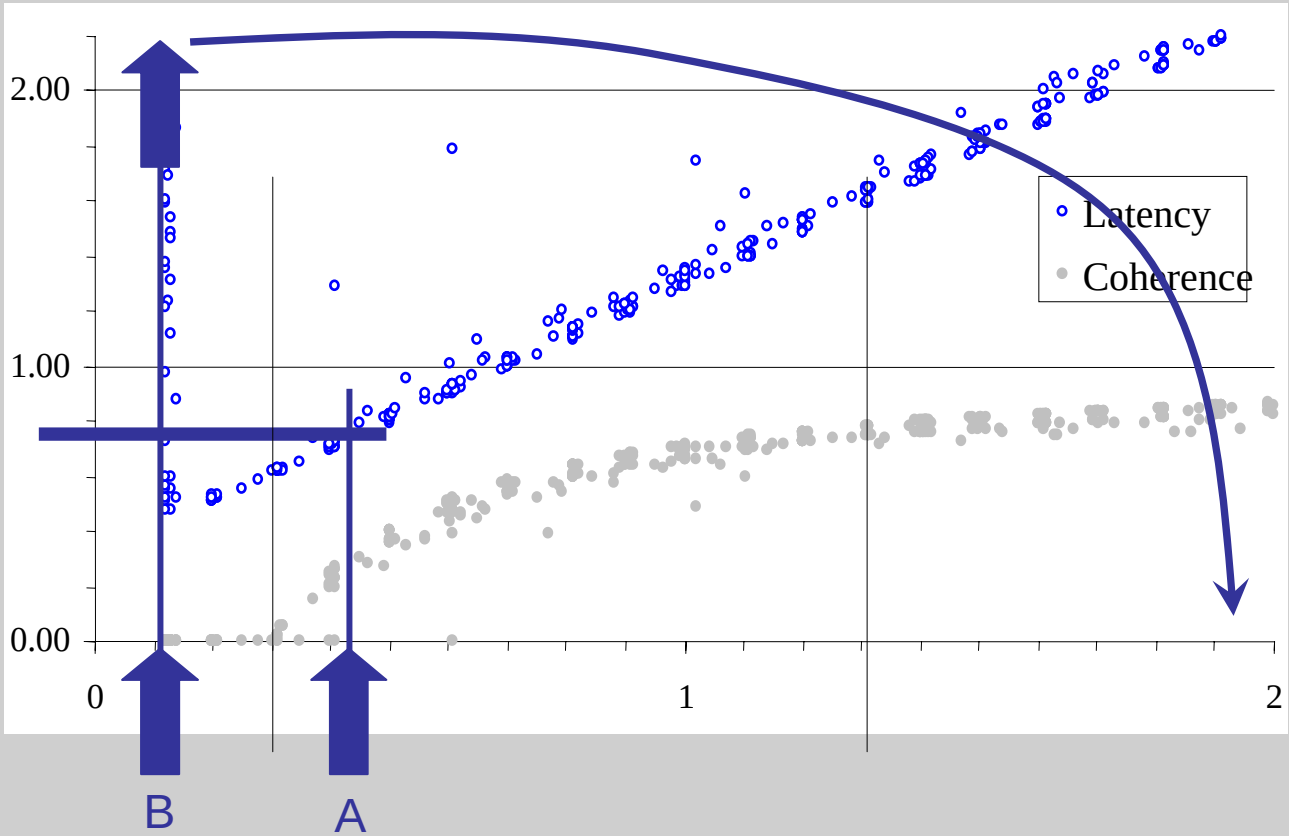
# The coherence interval



# The control paradox

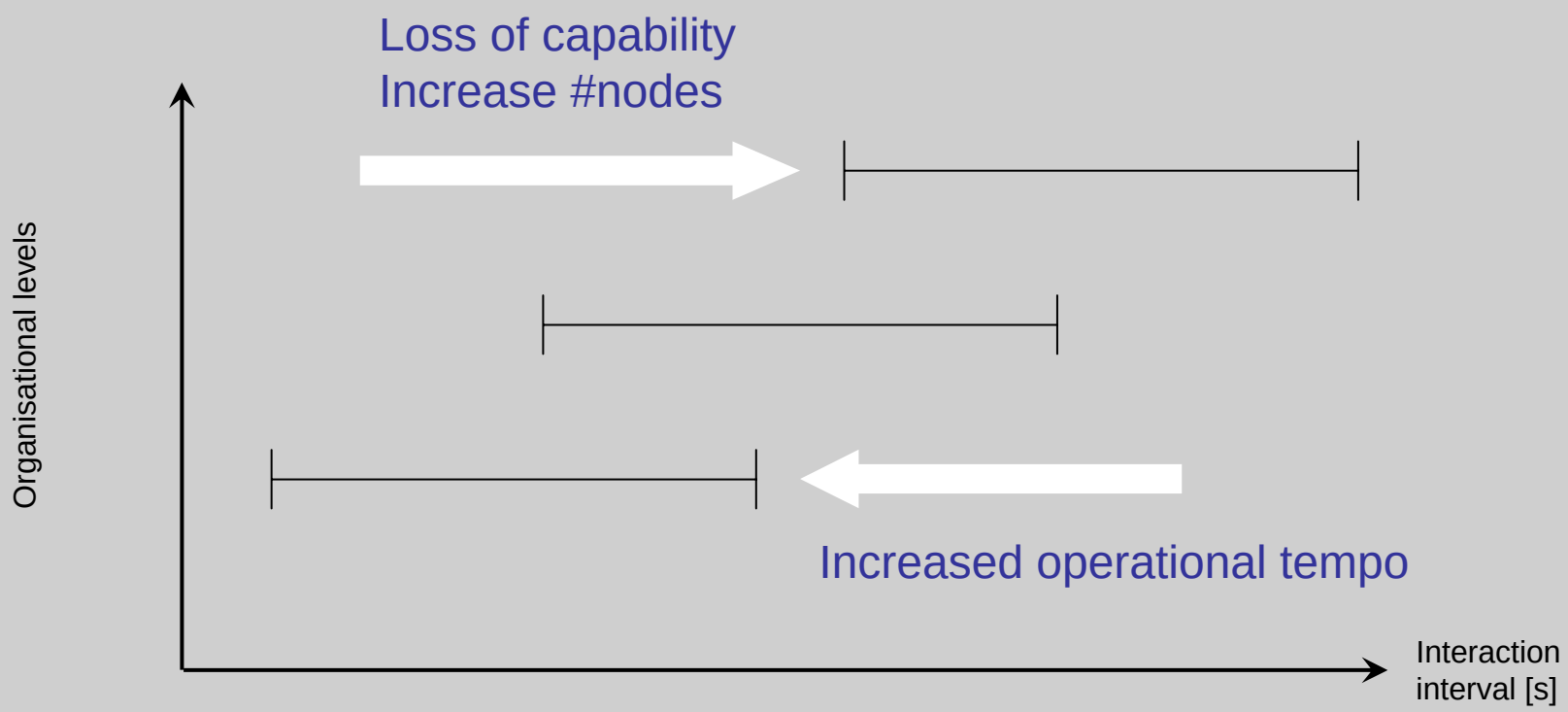
Shortening the interval between messages sent

may in fact increase the age of messages arrived

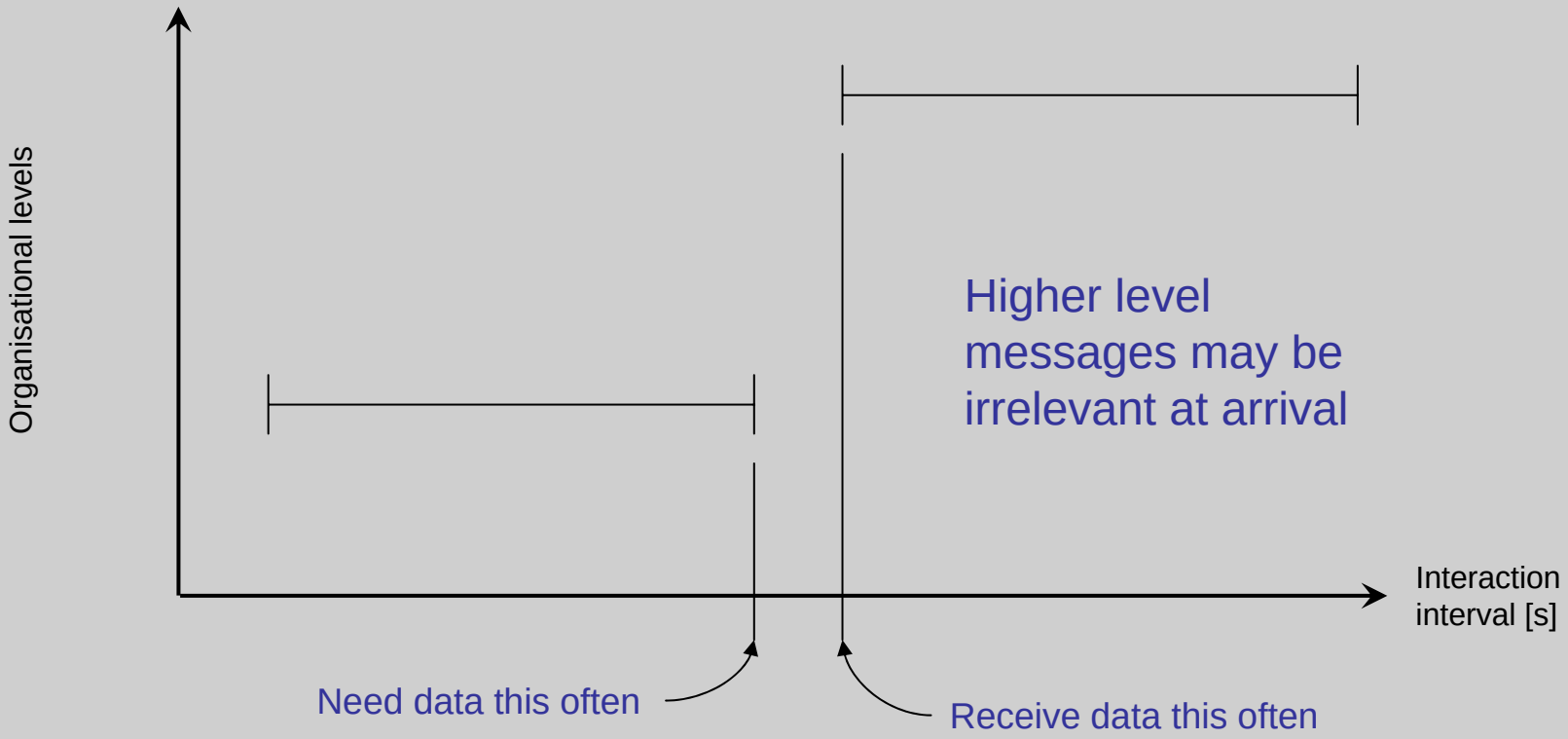



Increasing demands above some threshold actually makes data too old

# Coherence intervals revisited – operational dynamics



# Organisational decoupling

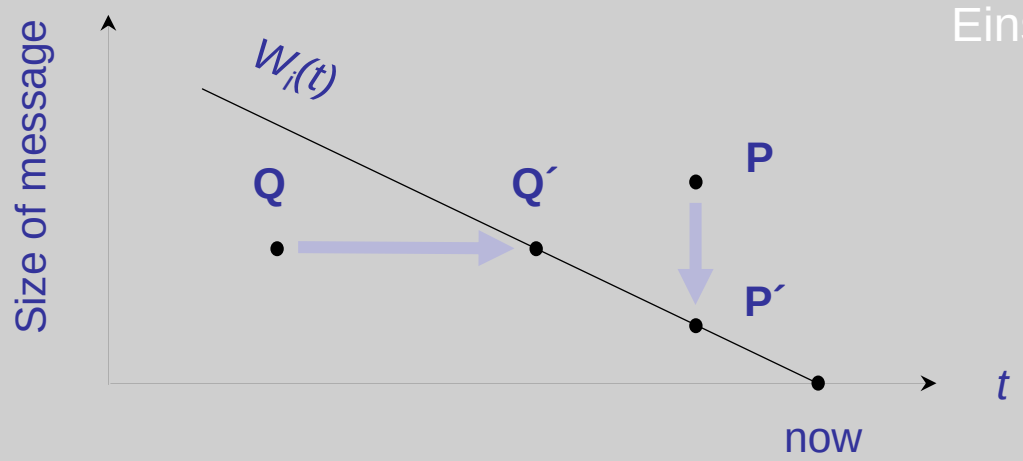


## Relative simultaneity

- Data transfer is subject for latency and saturation phenomena
  - When receiving data, we do not know how old it is
    (If we try to send ”too much”, data can become very old)

- So all data received is old (as also defined by ”distributed systems”)
- And even though data arrives ”now”, its actual age may vary
- These phenomena appear to be the same as described in the theory of special relativity, however then applied to light

Einstein-ish



## Conclusions

- Limitations to data coherence and data distribution in groups can be investigated with the time based models and methods described here

- A strong notion of simultaneously shared data does not hold
  - What latency do we have; how old data can we accept?
- Uncertainty phenomena put a lower limit to the resolution of measurements and observations in running, on line systems
  - And, asking for more information may take down a network

- Recognition of the coherence interval, the uncertainty phenomena and the relativistic simultaneity that manifest in distributed systems may provide further understanding of e.g., indeterministic behaviours and complexity
- It may also shed some light to mechanisms of command structure break downs, or predictions of e.g., the largest controllable group, given technical, temporal and environmental constraints

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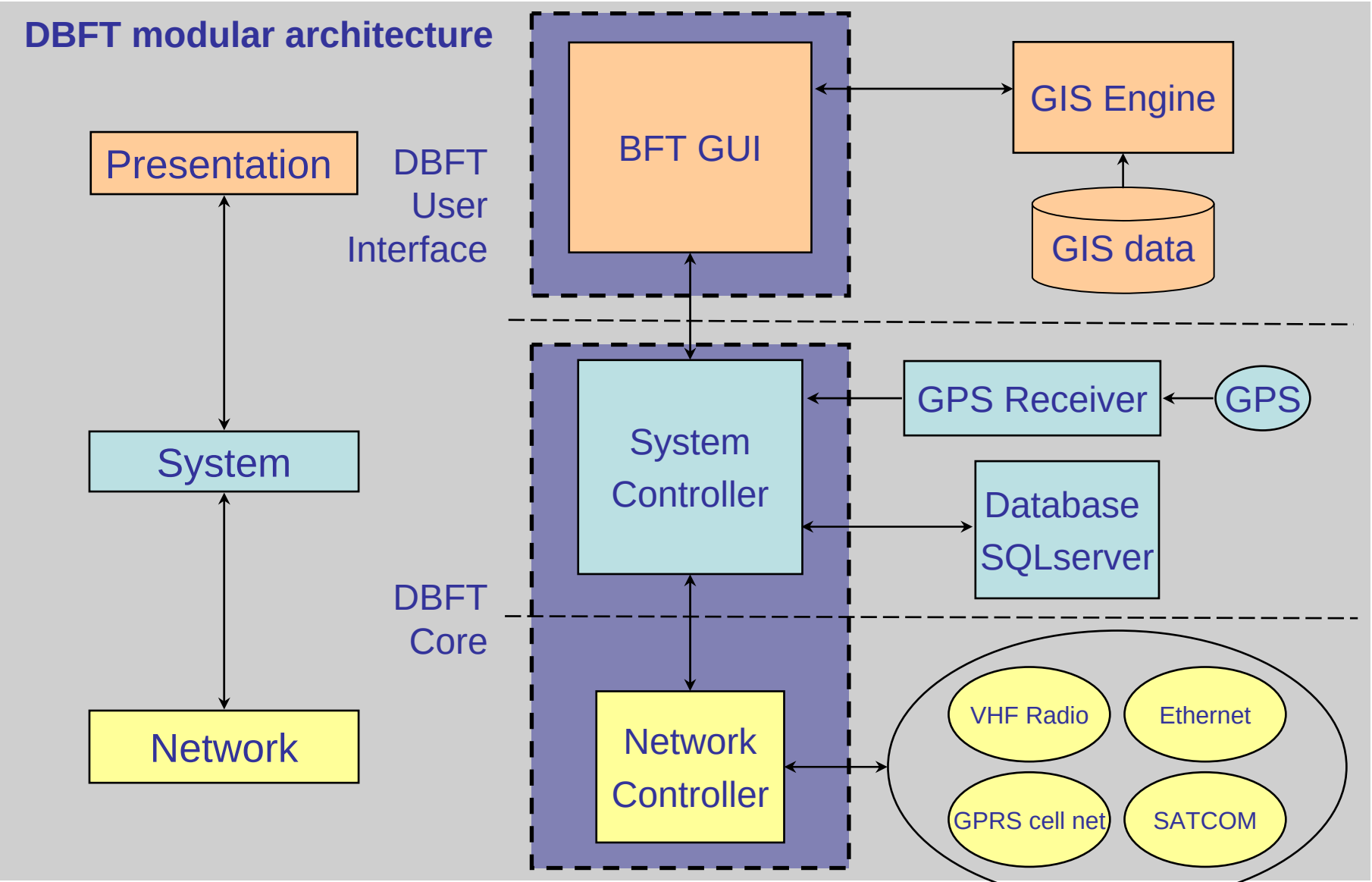
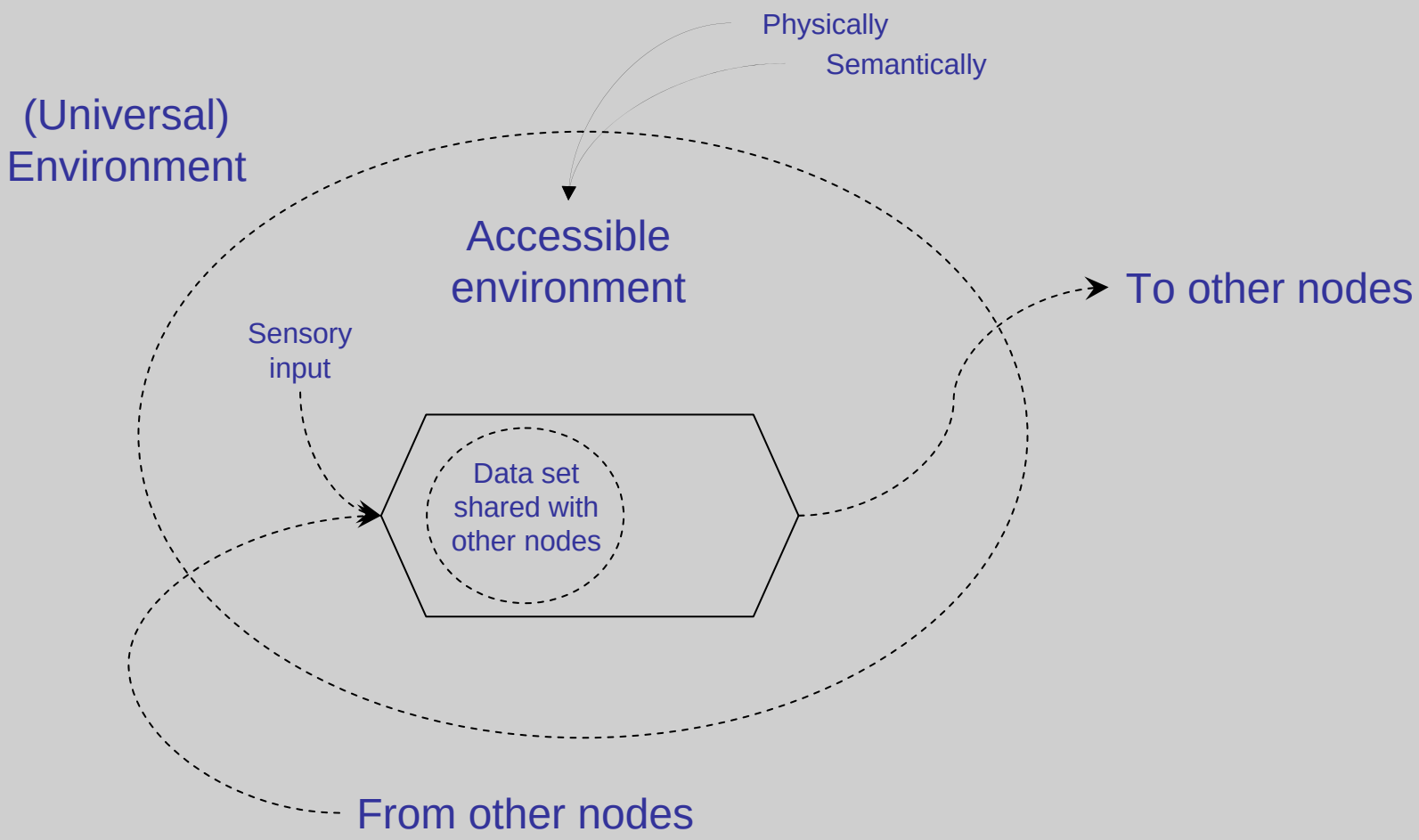
- Prof. Rune Gustavsson

Radius AB

# DBFT modular architecture



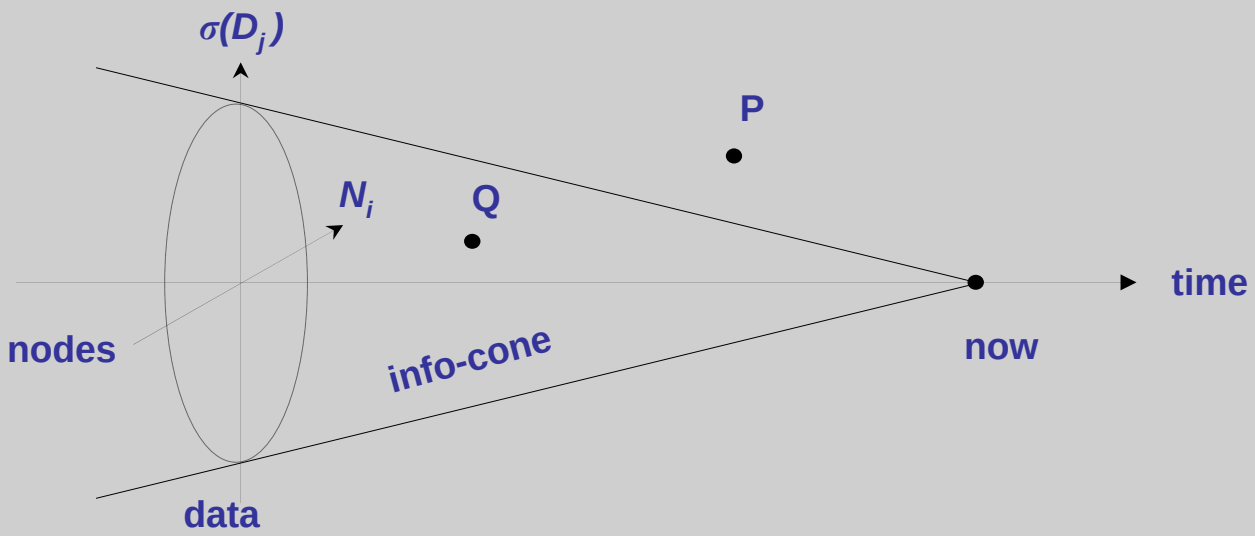
# Nodes – Environment model



## Inherent phenomena – uncertainty

- A coherent data set implies a definition of the state of the system
- Each unit maintains some behaviour, based on its current state
- The same resource is used for both handling messages (updating states) and creating behaviours

A group of units that are distributed in a changing environment can not at the same time both maintain a coherent state description of the group and provide an ”ideal” behaviour.

The larger the variation of the environment that is to be described, the larger the minimal size of a message need to be. Therefore, the lowest interaction interval will increase with the generality of the domain description. Specialized systems will react faster than general systems.

# The info-time cone