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# Optimising Shared Awareness in Communication Constraint Sensor Networks

Leon Kester


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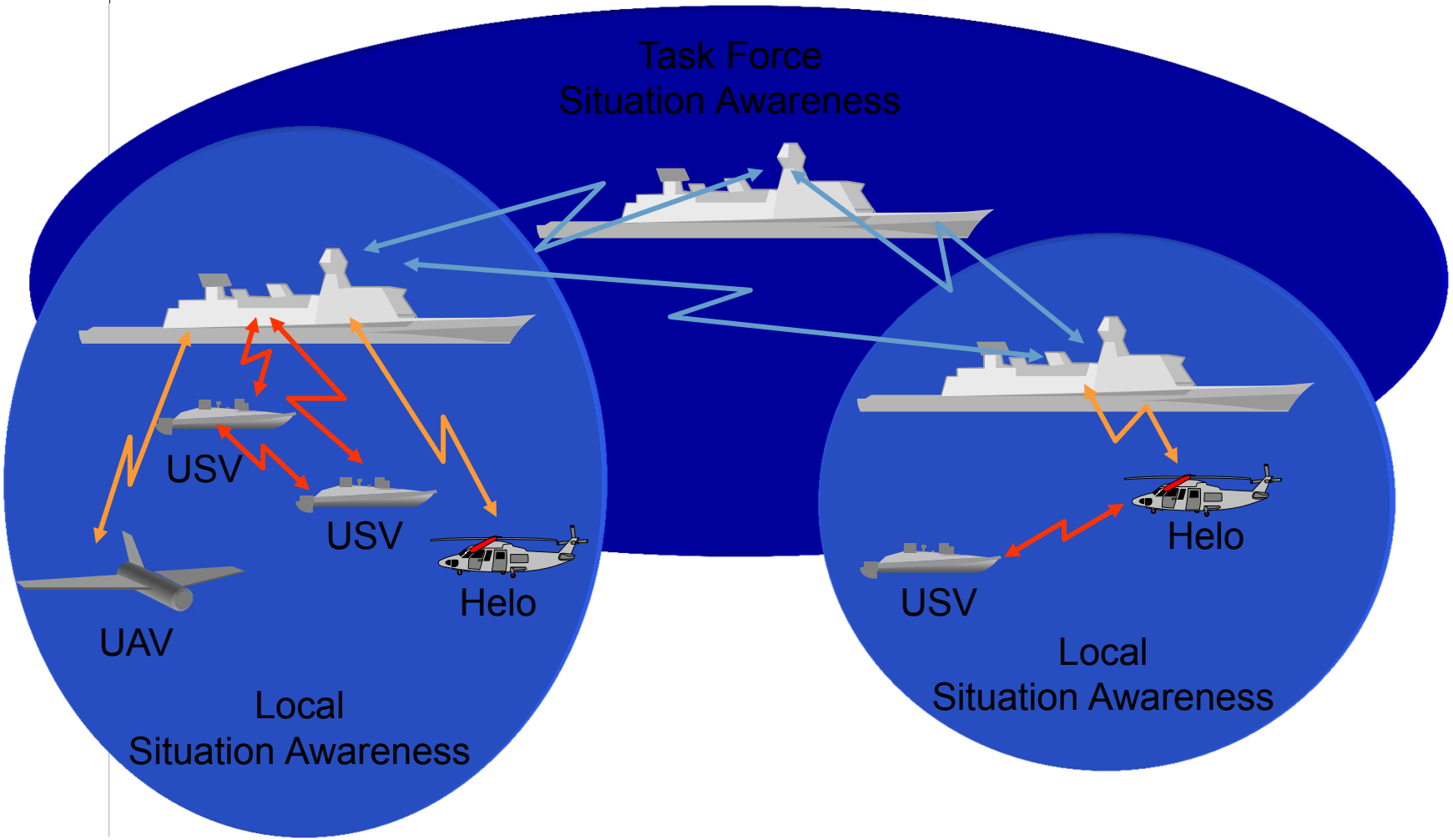
# Outline

- **Applications**
  - Task Force, Cooperative Intelligent Cars, Camera Network
- **Intelligent Systems**
  - Challenges, Hybrid systems, Adaptivity
- **Modelling Intelligent Systems**
  - Decomposition, Adaptivity: Self-organisation and Self-optimisation
- **Optimisation by balancing value and cost of communication**
  - Utility and Value of information, Cost of communication

# Situation Awareness in a Task Force



# Situation Awareness in a Task Force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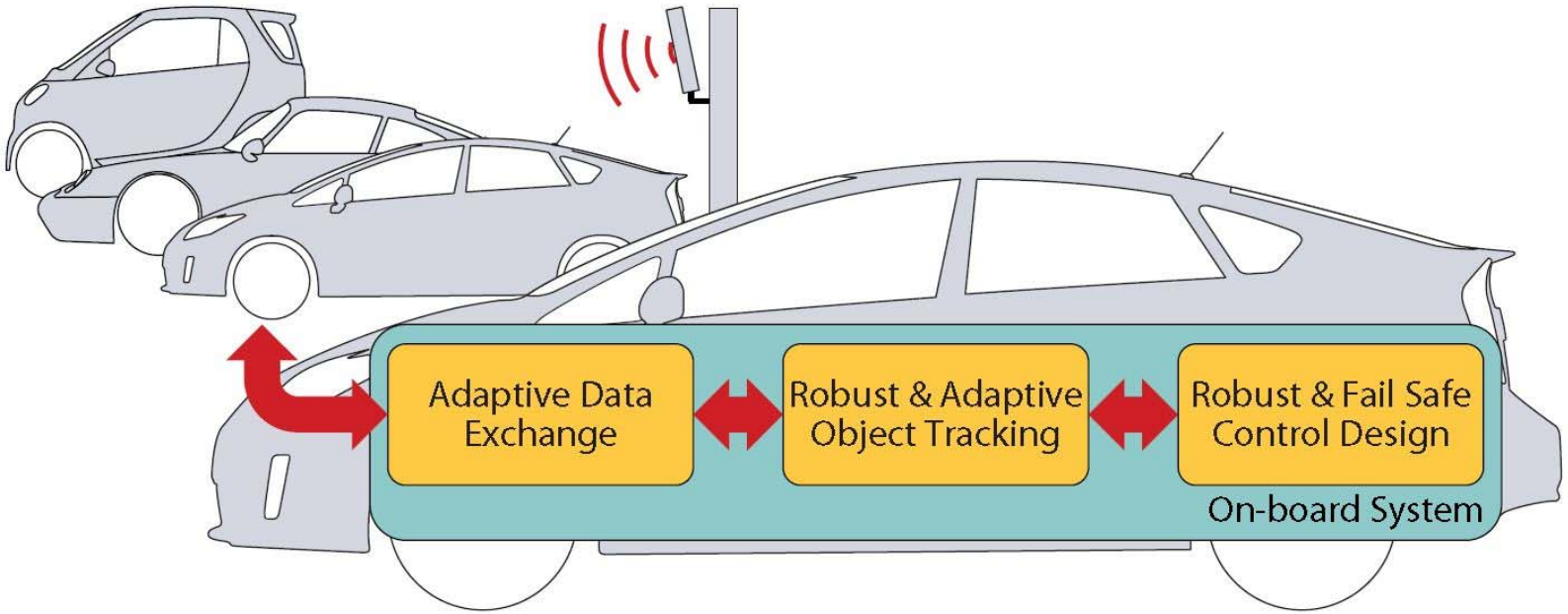
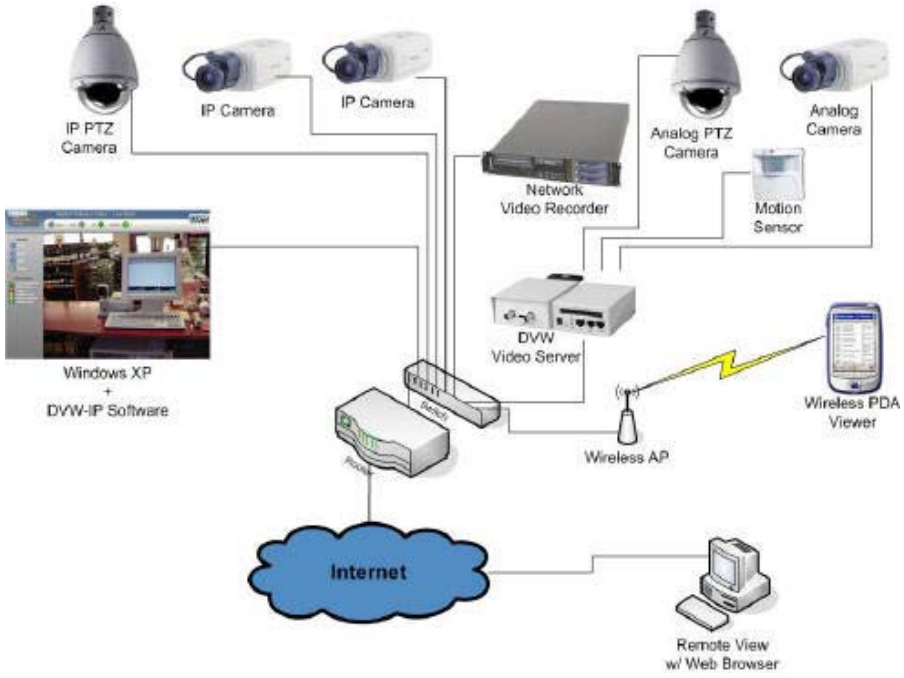
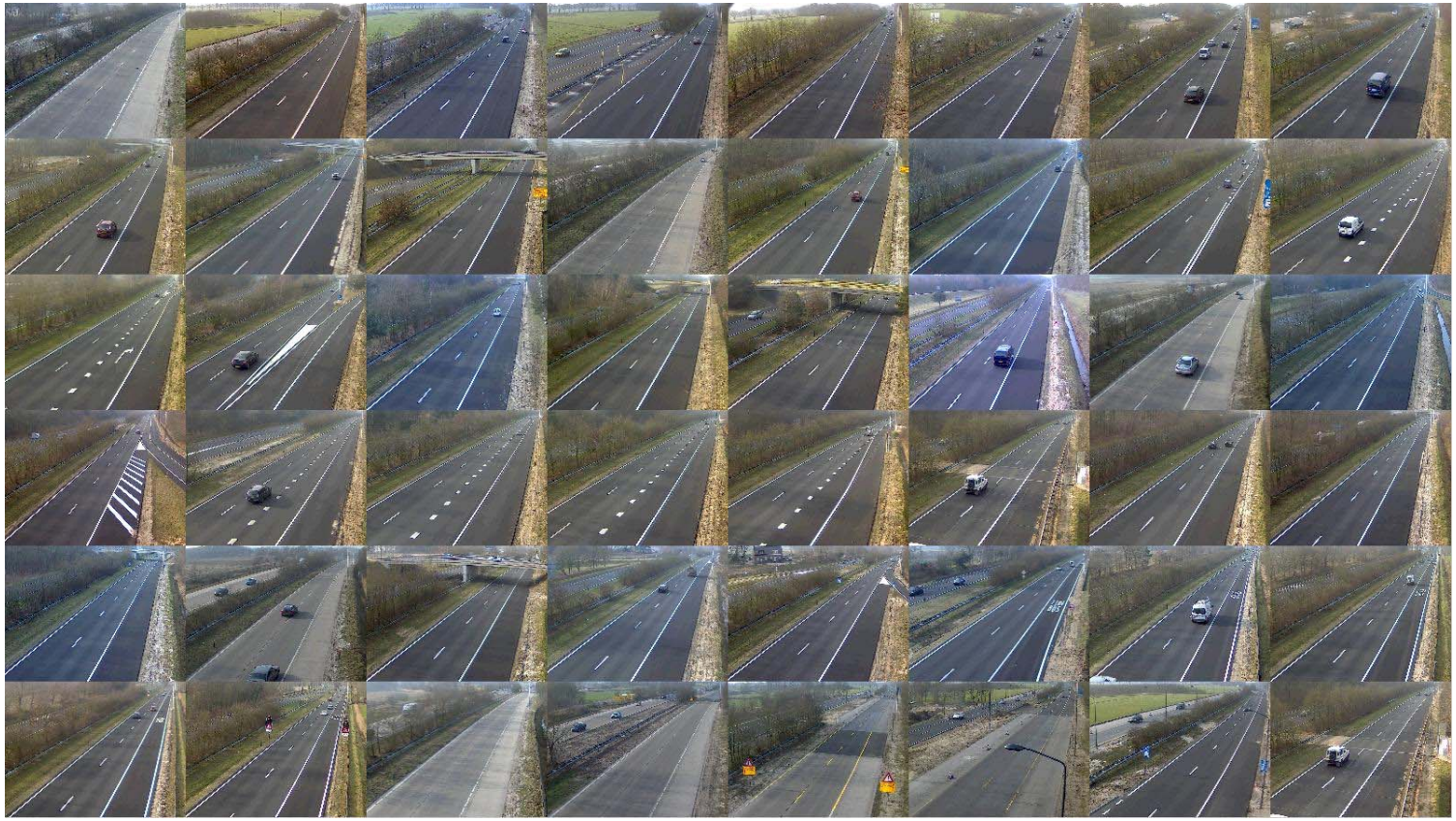
# Situation Awareness in Cooperative Intelligent Cars



# Situation Awareness in Camera Network




# Situation Awareness in Camera Network

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# Why optimisation?

- Information needs may depend on the situation
- Constraints in Communication may depend on the situation
- This requires some intelligent behaviour of the system:
  - What is my goal?
  - What is my current state?
  - What can I do?
  - What is my plan?


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# Intelligent Systems: Challenges

Breugel: Tower of Babel (1563)

- Semantic interoperability
- Common system model
- No Design time thinking
- Clear/quantified goals
- Focus on efficiency
- Hammer only for nails


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# Intelligent Systems: symbolism - connectionism

- **Symbolism**: system exhibits intelligent behavior by manipulating symbols with formal rules
  - E.g. Chess computer, rule based reasoning
- **Connectionism**: system exhibit intelligent behavior without storing, retrieving, or otherwise operating on structured symbolic expressions;
  - Pattern matcher, dynamic neural network
- **Hybrid systems**: some mix, intermediate form or full integration of both views.


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# Intelligent Systems: Situated Adaptivity

- **What?**
  - System that can adapt to the situation in such a way that it becomes more efficient in reaching its implicit or explicit goals.
- **How?**
  - Internal management functions that can either reorganise or optimise core system functions (Hybrid approach)
- **Why?**
  - If systems need to perform in a wide variety of situations adaptivity is more efficient.


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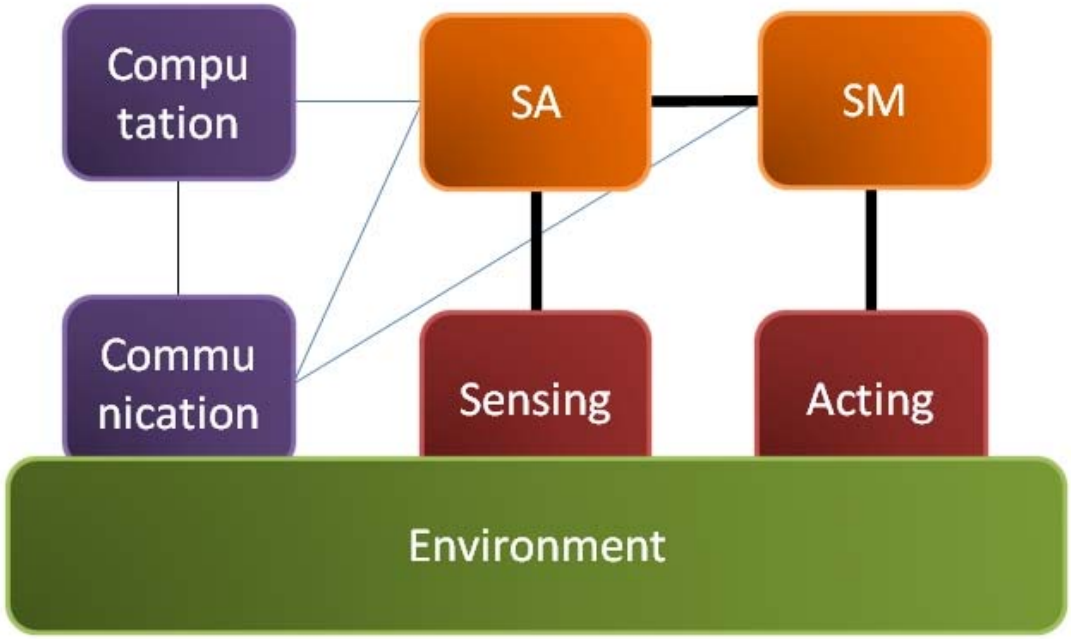
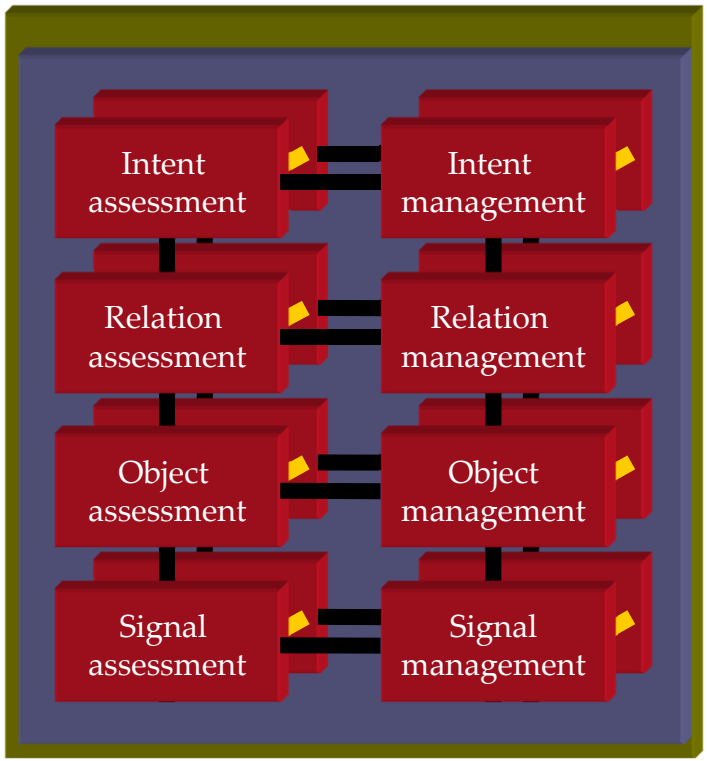
# System modeling: Basic functions

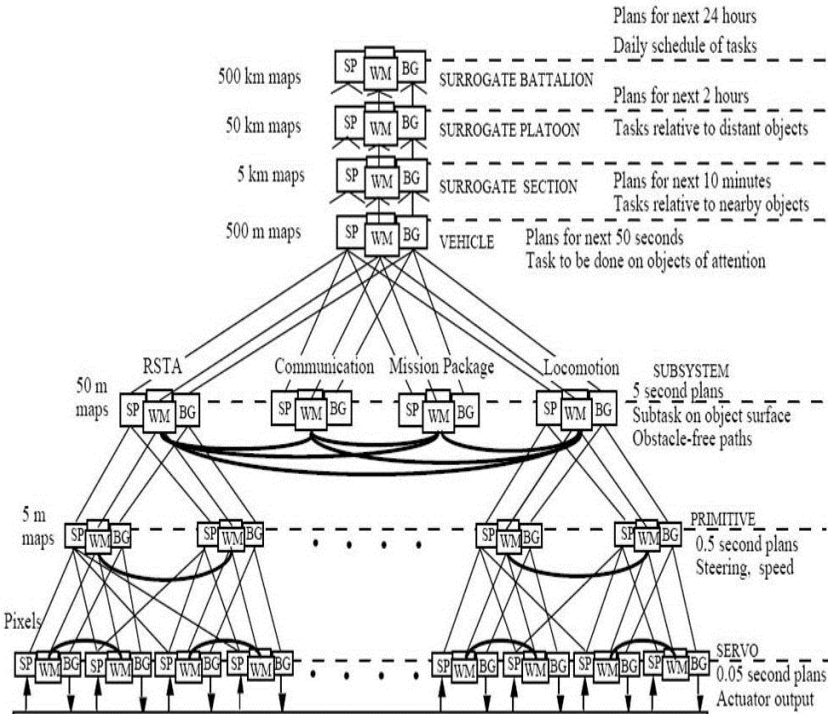


# System modeling: Hierarchy




JDL

situation abstraction




4D/RCS

&

space time abstraction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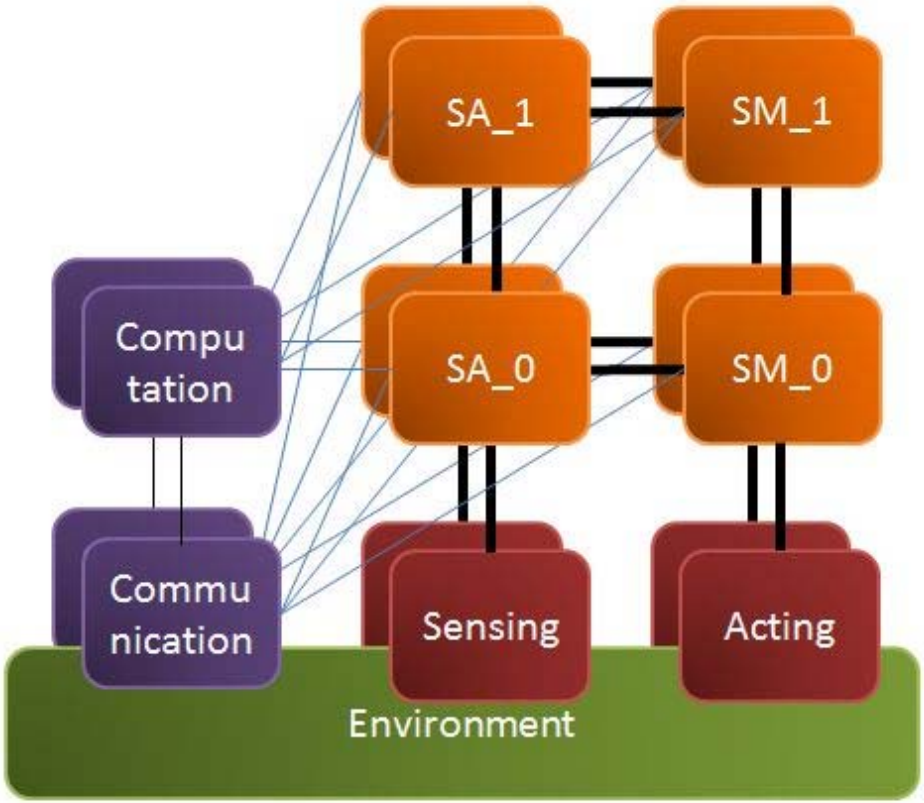
# Distributed intelligent systems with hierarchy





# System modeling: Adaptive systems

- Service oriented architectures
- Multi agent systems
- Dynamic Bayesian networks
- 4D/RCS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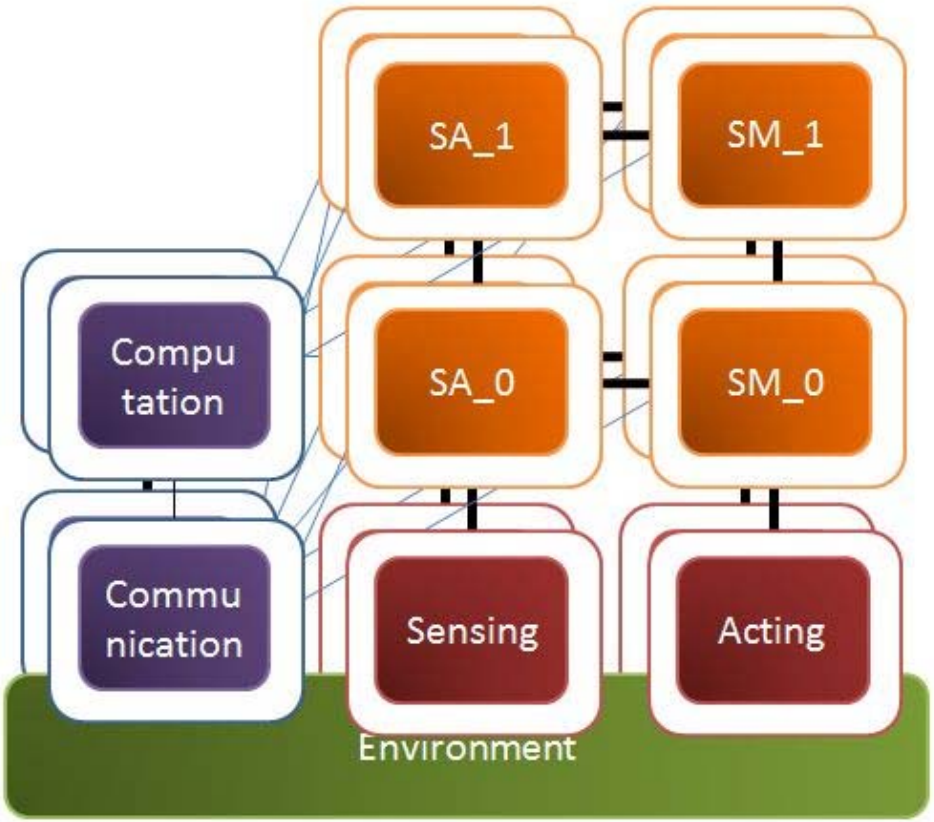
# Adaptivity: self-organisation & self-optimisation

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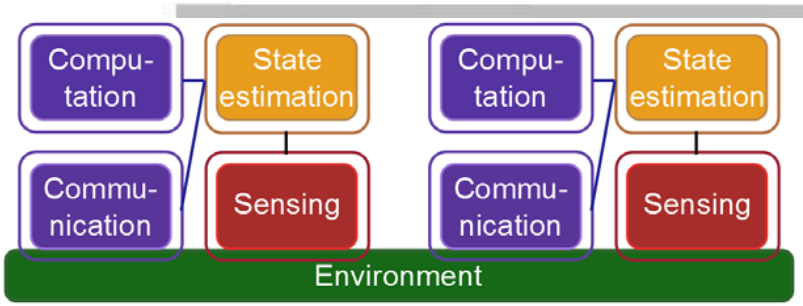
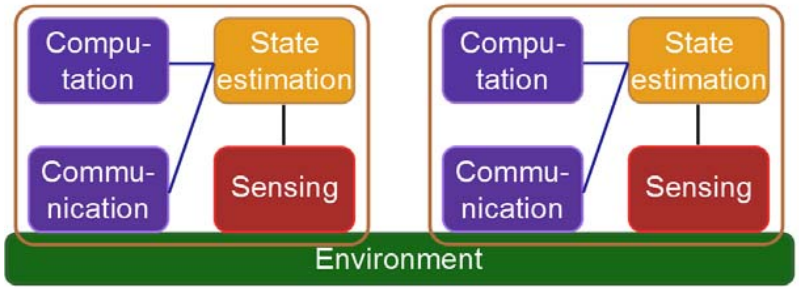
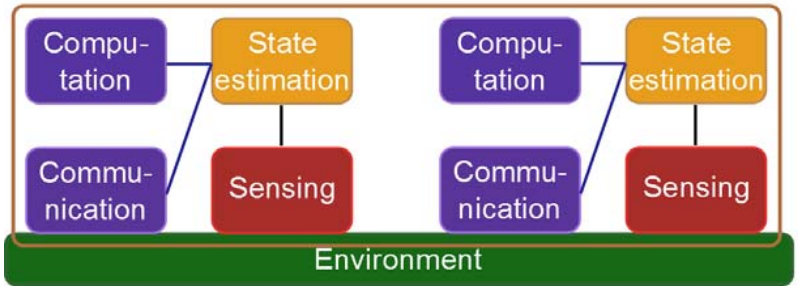
# Centralised or decentralised adaptivity




A setup of two nodes, where *each* core-functionality/resource is surrounded by a supportive shell-functionality for self-organisation & self-optimization




A setup of two nodes, where the core-functionalities/resources are surrounded by a supportive shell-functionality *per node* for self-organisation & self-optimization




A setup of two nodes, where the core-functionalities/resources of *both nodes* are surrounded by a *centralized* shell-functionality for self-organisation & self-optimization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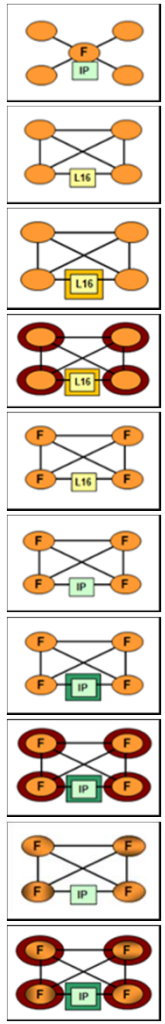
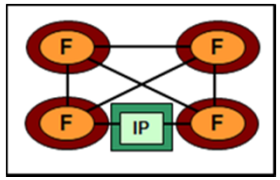
# SA concepts

- Concept 1.1: Centralised measurement fusion
- Concept 2.1: Link 16
- Concept 2.2: Link 16 enhanced
- Concept 2.3: Link 16 smart evaluation
- Concept 2.4: Link 16 track fusion
- Concept 3.1: Decentr. measurement fusion
- Concept 3.2: Decentr. measurement fusion smart network
- Concept 3.3: Decentr. measurement fusion smart network smart eval.
- Concept 3.4: Decentr. measurement fusion non-identical algorithms

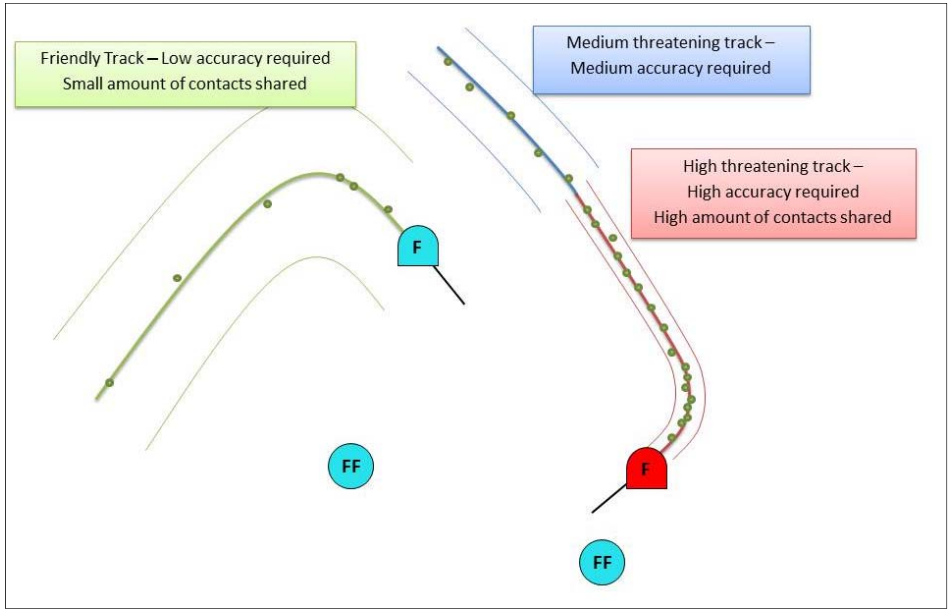



# Concept 3.3

## Decentr. measurement fusion smart network smart eval.

- Utility Function: accuracy,

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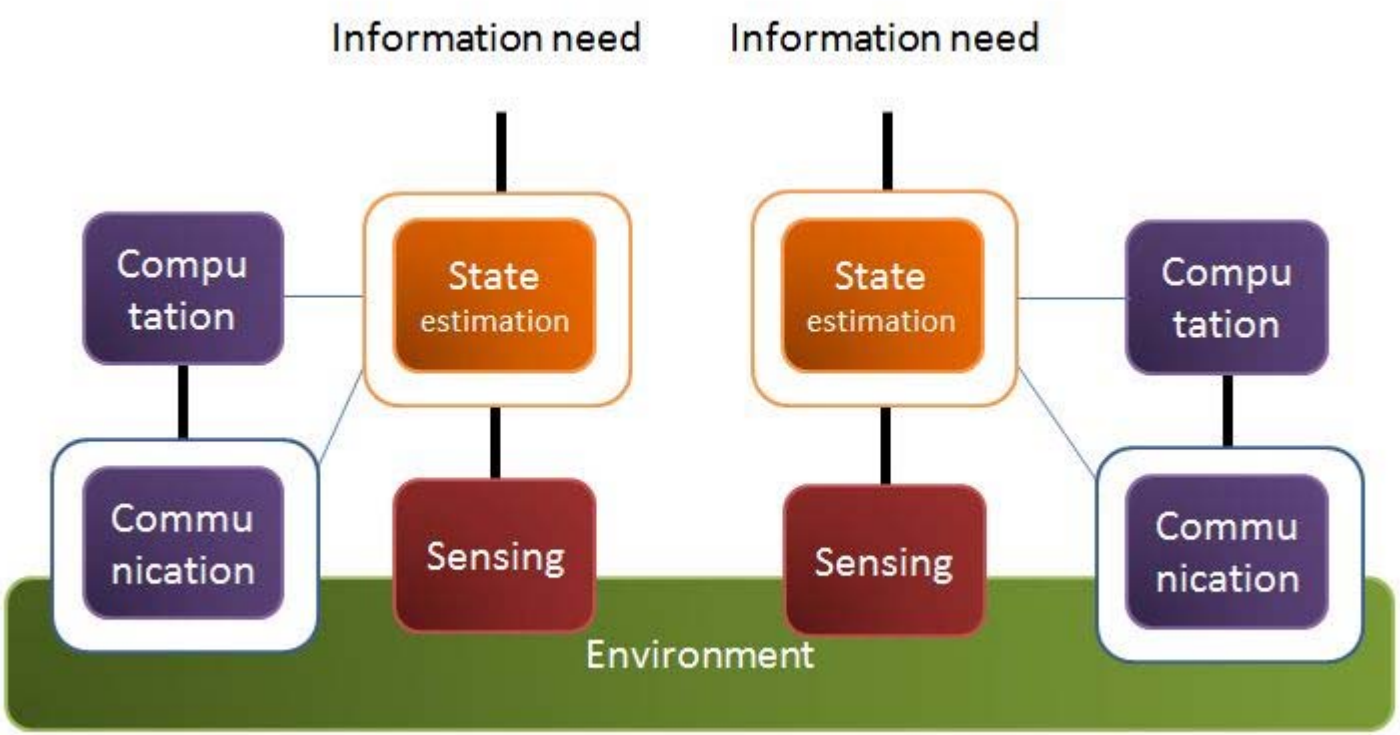
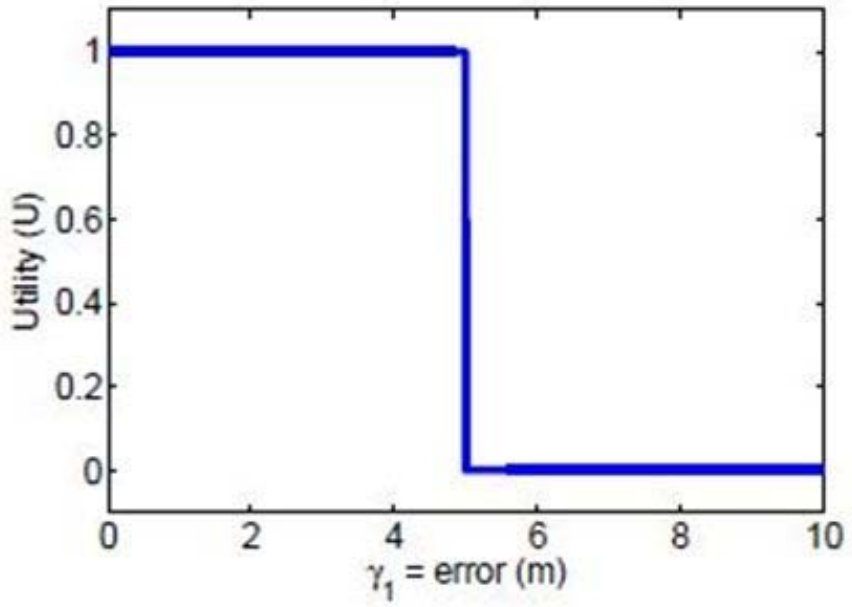
# Self-optimisation with communication constraint

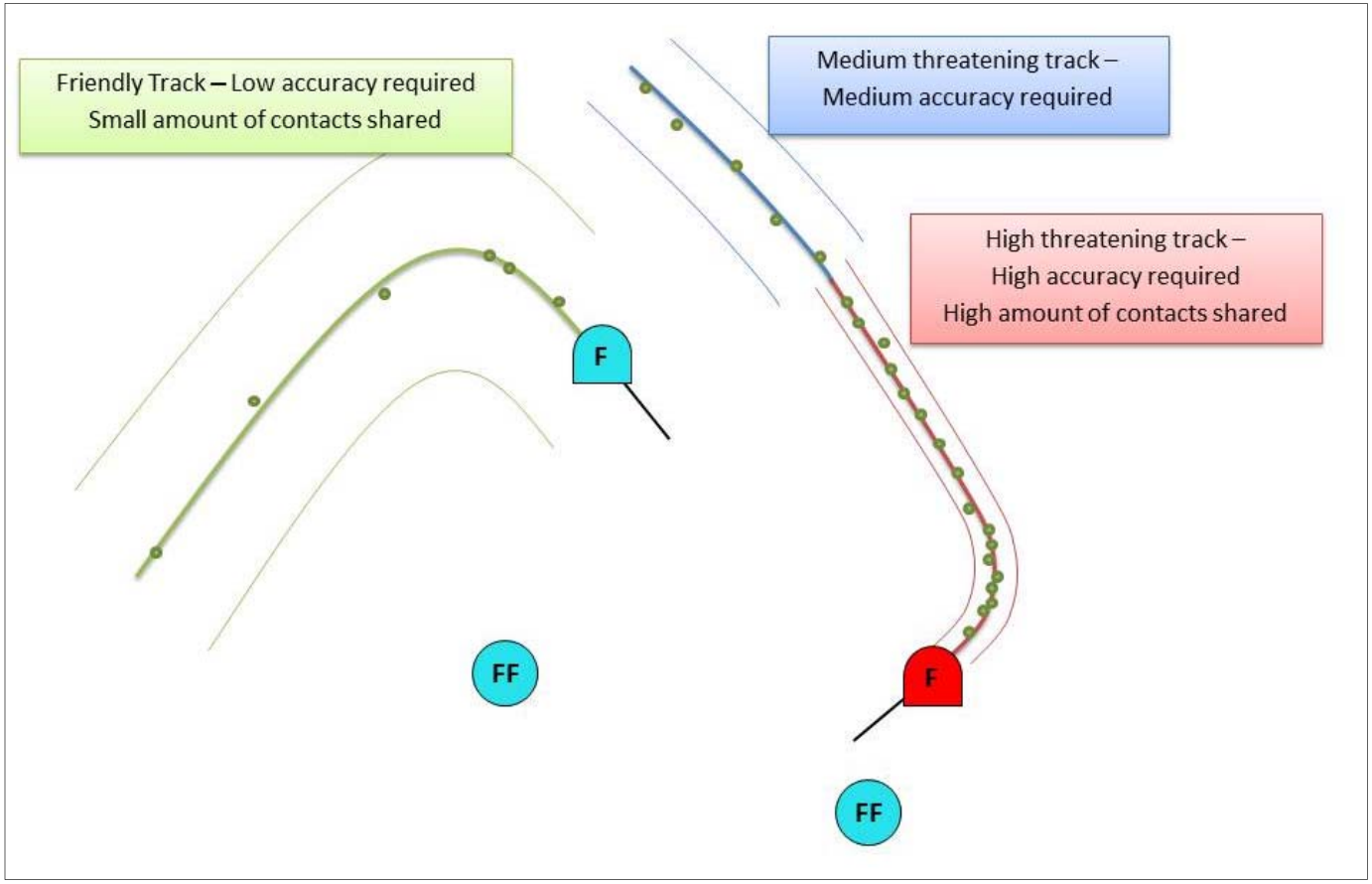


# Balancing value of information and cost of communication

*Information need: Utility function (an example)*



# Utility function can be object specific

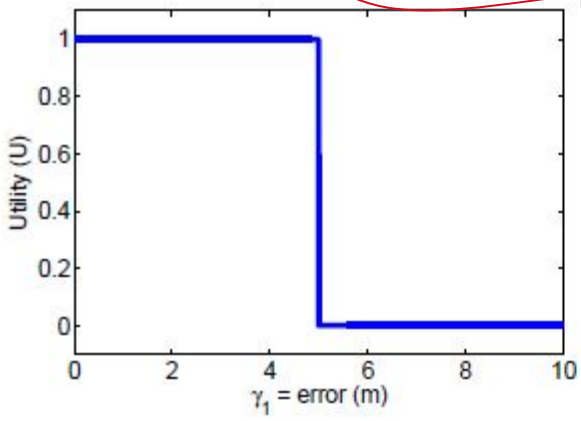


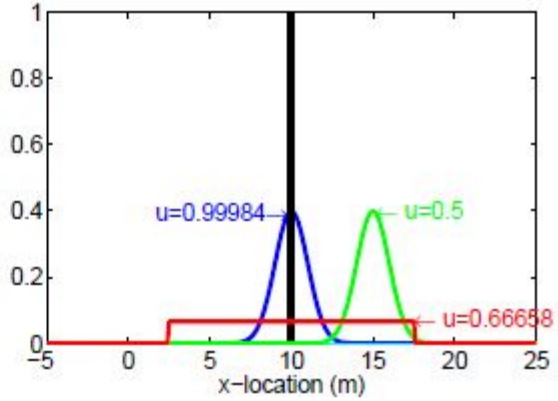
# The Value of New Information

Utility function with respect to a reference state

$$\mathcal{U}\left(\Gamma\left(\hat{p}_r,\hat{p}\right)\right)=\iint U\left(\Gamma\left(\vec{x}_r,\vec{x}\right)\right)\hat{p}\left(\vec{x}\right)\hat{p}_r\left(\vec{x}_r\right)\,\mathrm{d}\vec{x}\mathrm{d}\vec{x}_r.$$

Utility function




$$\hat{v}\left(\hat{X},\mathcal{Z}\right)=\mathcal{U}\left(\Gamma\left(\hat{X}_r,\hat{X}|\mathcal{Z}\right)\right)-\mathcal{U}\left(\Gamma\left(\hat{X}_r,\hat{X}\right)\right).$$

New Information

Reference state

Current state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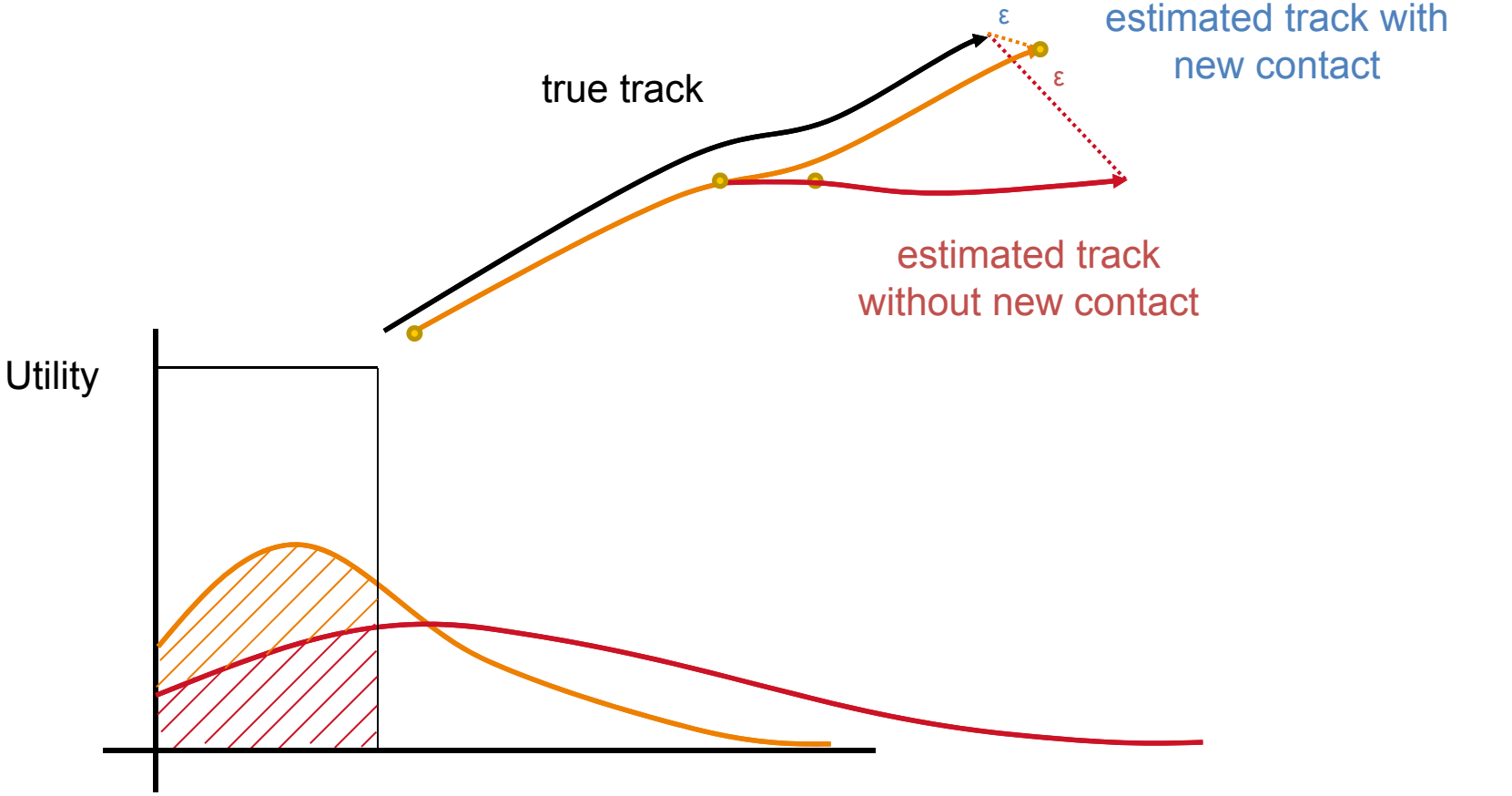
# The Value of New Information




$$\hat{v}\left(\hat{X}, z\right) = u\left(\Gamma\left(\hat{X}_r, \hat{X}|z\right)\right) - u\left(\Gamma\left(\hat{X}_r, \hat{X}\right)\right).$$

New Information

Reference state

c

Current state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# Cost of communication

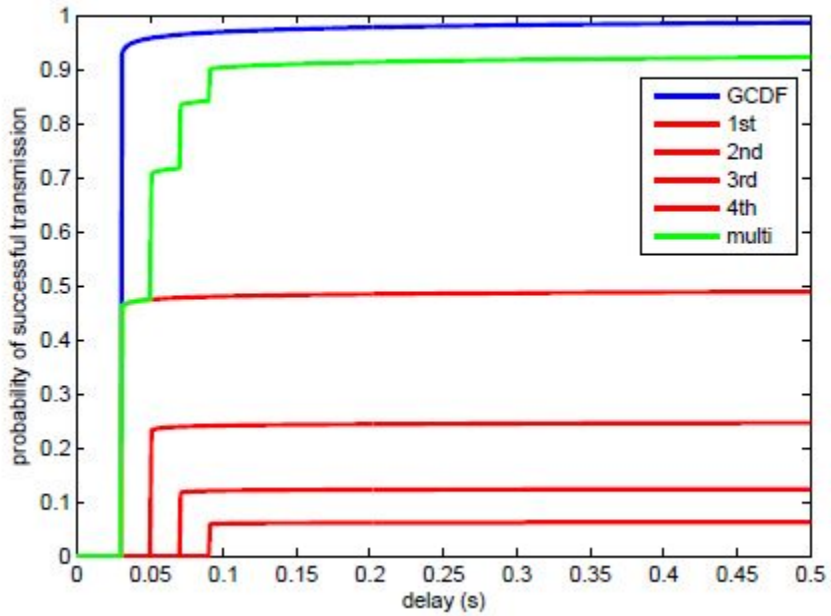
Expected delay distribution

$$\hat{P}(t,\mathcal{Z},\mathcal{S}) = \sum_{n}^{N} p(\mathcal{S},n) \prod_{a=1}^{|\mathcal{S}|} \mathcal{G}\left(t - \Delta t_{\text{det}}(a,n)\right).$$

Expected cost of communication

$$\hat{c}(n,\mathcal{Z},\mathcal{S}) = Fn\frac{TB\sum_{a=1}^{|\mathcal{S}|} P(a)}{T_{\text{tot}}P_{\text{tot}}B_{\text{tot}}},$$

$$\hat{\mathcal{C}}(t,\mathcal{Z},\mathcal{S}) = \sum_{n=1}^{N} \hat{c}(n,\mathcal{Z},\mathcal{S}),$$



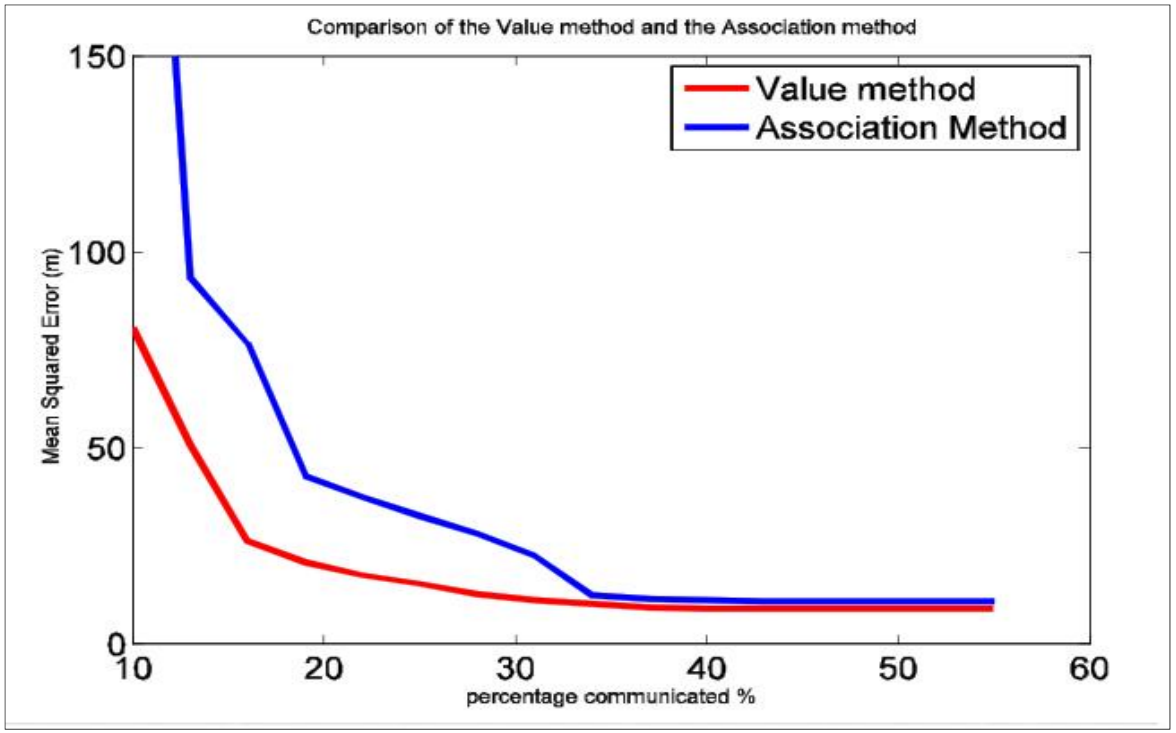



# Expected Reward Function

$$\hat{\mathcal{R}}(\hat{X}, \mathcal{Z}, \mathcal{S}) = \hat{\mathcal{V}}(\hat{X}, \mathcal{Z}) - \hat{\mathcal{C}}(t, \mathcal{Z}, \mathcal{S}).$$

$$\hat{\mathcal{R}}\left(\hat{X}, \mathcal{Z}, \mathcal{S}\right) = \sum_{n=1}^{m} P(\Delta t_n, \mathcal{Z}, \mathcal{S}) \left(\hat{\mathcal{V}}\left(\hat{X}, \mathcal{Z}\right) - \hat{\mathcal{C}}(\Delta t_n, \mathcal{Z}, \mathcal{S})\right) - P_f \sum_{n=1}^{m} \hat{\mathcal{C}}(\Delta t_n, \mathcal{Z}, \mathcal{S}).$$

# The Value of new Information

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# Applications next year

- Cooperative Adaptive Cruise Control
- Dynamic Map of traffic including floating car data
- Task Group Awareness for Command and Control
- Awareness in autonomous underwater, surface and air vehicles
- Camera Network for Surveillance
- Smart Grids


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# Questions ?

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