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CENTRE FOR WIRELESS COMMUNICATIONS
University of Oulu

Distributed and hierarchical wireless sensor network for area surveillance

An overview

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Introduction

- Nowadays, information and status of the neighborhood is a key feature in different application areas
- Reliable real-time detection of environment, i.e. enhanced situational awareness, is a vital requirement in any military and peace-keeping operation.
- Similar operational demands are valid also in many civilian safety and surveillance applications
  - multi-use systems are needed for modern applications

- Wireless sensor networks can compensate for human presence and/or assist human observations in area monitoring allowing
  - easy deployment
  - cheap HW and operational costs
  - automated network configuration

Introduction

- In wireless and movable area surveillance applications, energy efficiency is one of the most important design factors
  - sensor nodes, as well as the whole network should be designed to consume as little energy as possible to ensure long life time for the system
  - typically, the biggest energy consumer is *radio!*
  - other major energy consumers are different kind of detectors
- The idea is to apply a reactive approach to sensing, computation and communication throughout a wireless sensing system distributing intelligence within a network
- In the system, neither a reactive system nor its component does perform any function unless it is explicitly indicated to do so through some external stimulus

Introduction

- Fundamental problem in the emerging sensor network technology is that the traditional OSI layered system architecture is not best suited for the design of wireless sensor networks.
- With extremely limited energy and computational resources of wireless sensor nodes combined with fundamental problems related to the wireless transmission medium, it is no longer possible to hide run-time parameters of a particular protocol behind simplified interfaces between OSI layers.
- Thus, the new way is to obtain cross-layer design approach between different OSI layers

Wireless area surveillance network (WAS)

WAS

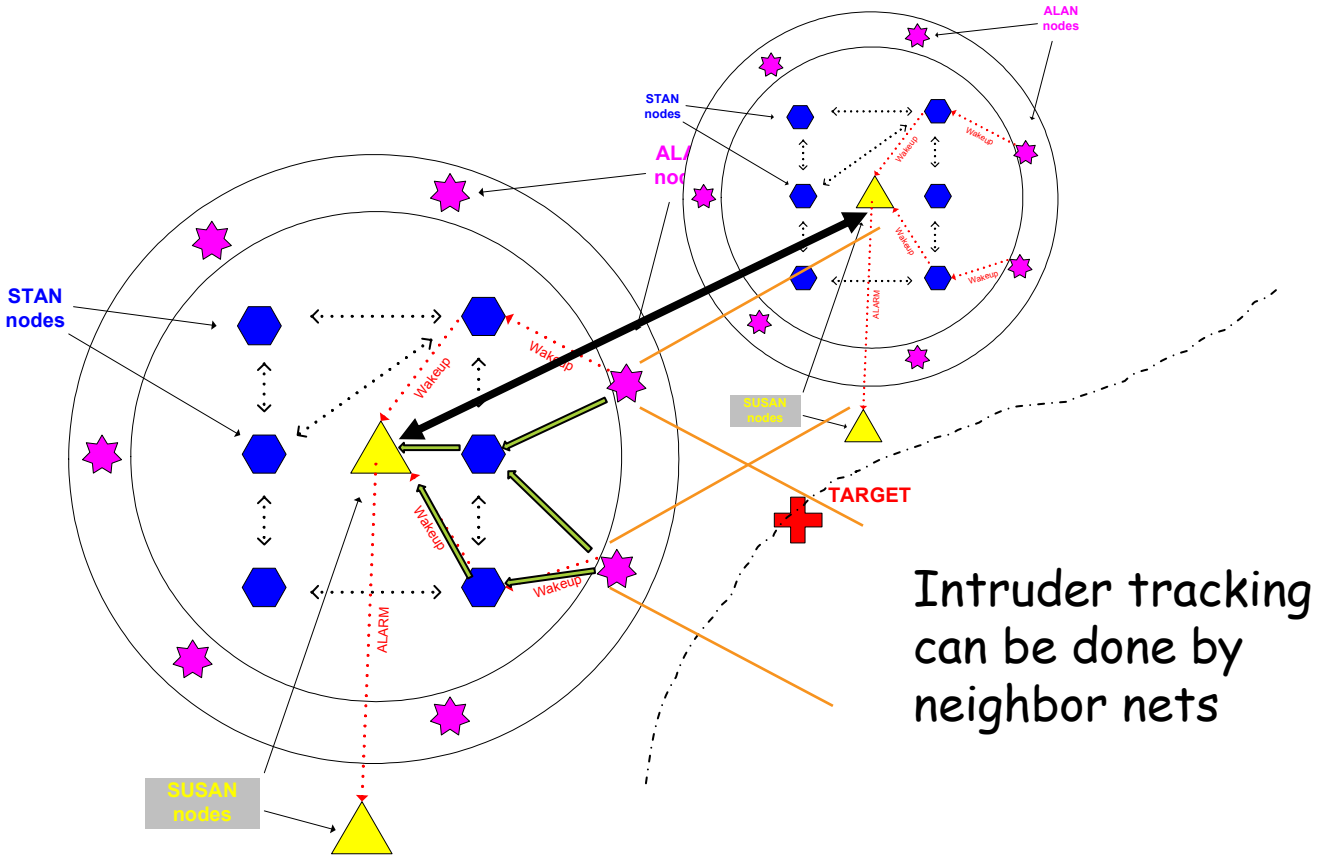
- The activation signal can be any predefined detector originated event (change in temperature, magnetic field or humidity, infra red, acoustic, vibration, shaking, camera, etc.)

- Heterogeneous network topology
  - different radio interfaces
  - different network topologies
  - variable set of detectors/sensors

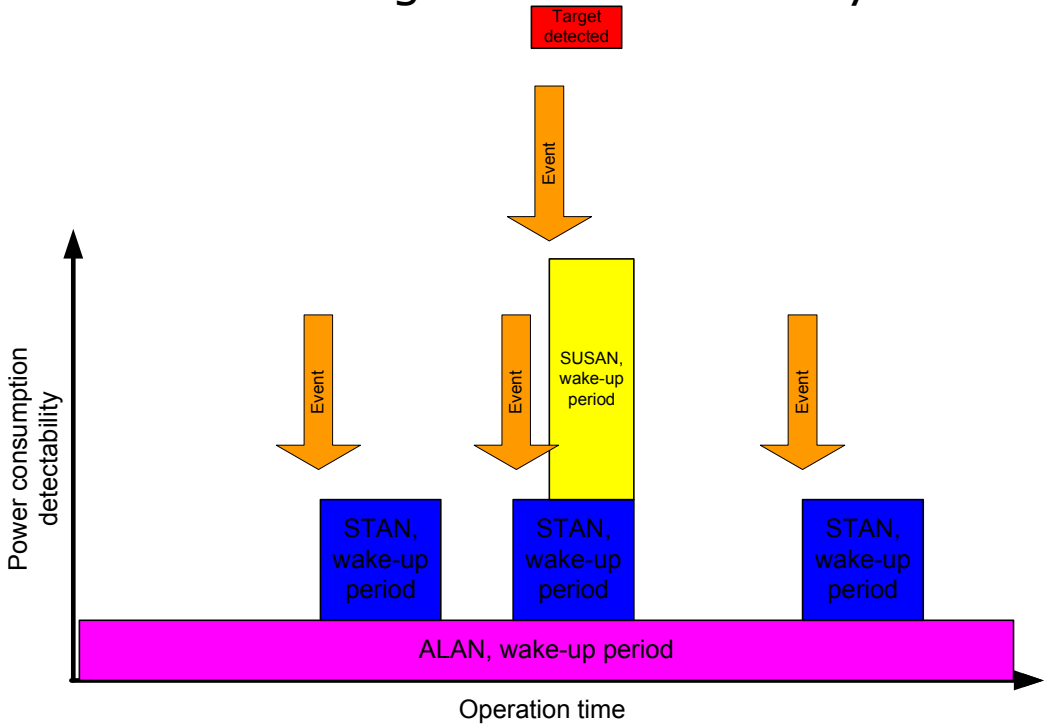
- WSN consists of devices that can be randomly distibuted to an environment to cooperatively monitor its condition or activity
  - flexible
  - scalable

The system

- The network includes the following parts:
  - ALArm Network/node (ALAN)
  - Surveillance and TArget tracking Network/node (STAN)
  - SUper Secure Access Network/node (SUSAN).



- Energy consumption will be controlled by assigning different hierarchical layers so that, in general, the probability of a certain layer being activated is inversely proportional to the energy consumed by it.
- Cross-layer protocol optimization techniques to improve the network performance will be thoroughly investigated in the context of this layered architecture. In principle, this kind of system follows the basic idea of wake-up radio, in our case, it is even based.
- Distributed decision making within a hierarchy



EVENT based wake-up - ALArm Network

- ALAN nodes are extremely simple, equipped with just a very simple set of sensors
  - For example, IR sensors or UWB radars which are able to detect targets based on the movement inside the area under surveillance.
- Detectors in ALAN do not need to be similar.
  - Different stimulus for wake-ups
  - Treshold
- ALAN nodes are also equipped with extremely simple radio interface which is activated only when a node detects an event.
  - Long life time
- In these occasions, ALAN node sends a wake-up call to the higher hierarchical layer.
- Due to their very low power consumption, ALAN nodes can be active all the time.
- ALAN nodes establish the furthest ring of the surveillance network, which could have an arbitrary shape.
- Robust by overlapping monitoring sectors

Initial decision - Surveillance and TArget tracking Network

- The second ring is installed with STAN nodes which are equipped with variable set of sensor heads / detectors
  - e.g. sophisticated video equipment.

- Detectors in STAN do not need to be similar inside the network. Instead, it is even advisable that they are equipped with complementary set of sensors, which enable them to classify and track the targets in most optimal way.

- It is assumed that STAN nodes are sleeping until they receive a wakeup call from ALAN nodes. This requires some form of wakeup radio, or similar technology, to be used.

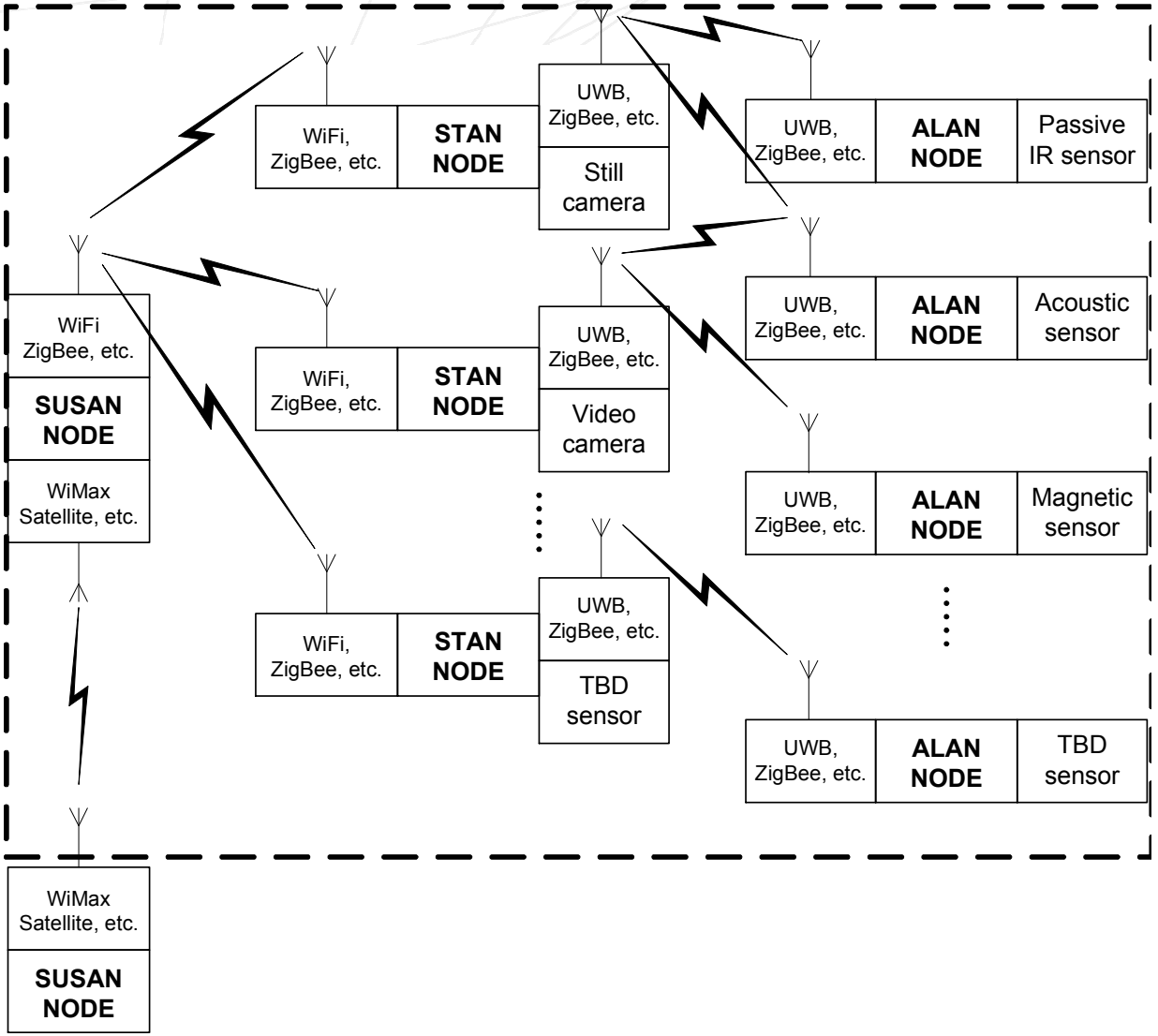
Initial decision - Surveillance and TArget tracking Network

- It is also assumed that if ALAN node observes a target, at least some of the STAN nodes are also capable to observe the same target.
- ALAN node can wake-up only the STAN nodes that are within its (presumably short) radio range. Alarmed STAN node can further decide to wake-up other STAN nodes in order to increase the observation tracking reliability.
- The wakeup call from ALAN to STAN must be extremely robust, so that it cannot be jammed, thus preventing the wakeup of STAN.

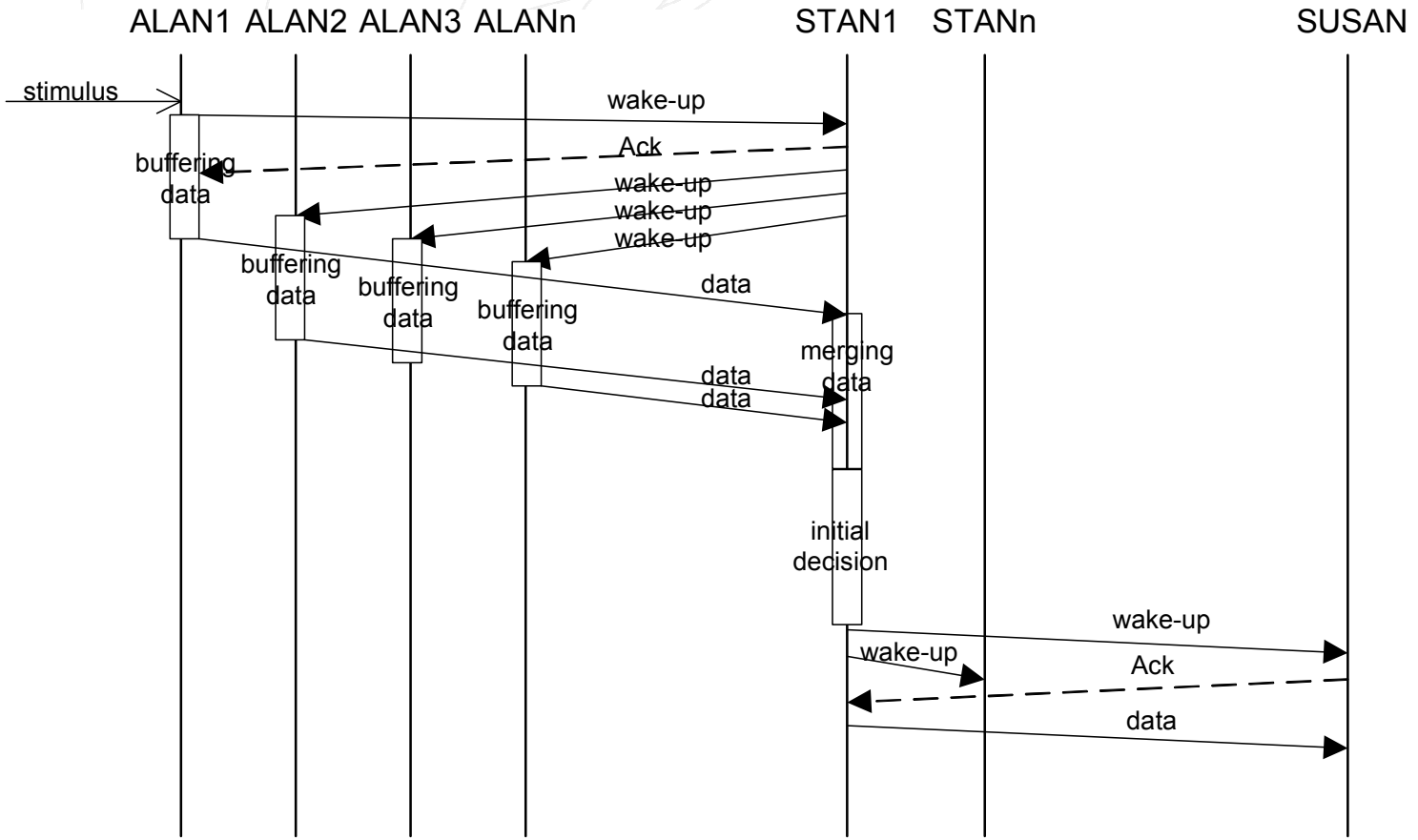
Final decision - SUper Secure Access Network

- SUSAN node receives the wakeup call from STAN node(s) and informs the outside operator or command centre about a possible event within the surveillance area of the sensor / monitoring network.
- SUSAN nodes form the highest and most secure hierarchy level of the network.
- SUSAN node has also the highest computational power within the network.
  - It is possible that there is only one SUSAN node in the area of the surveillance network.
- SUSAN node may have a peer far outside the surveillance area, or it can directly connect to somewhere outside the surveillance network
  - Such as command and control centre
- Connected SUSAN nodes make it possible to track, e.g., the intruder that is crossing adjacent surveillance sub-networks

WAS components



Interaction diagram



No time slots reserved for communication. All the traffic is initiated by the stimulus (event).
No network synchronization is needed which makes the network simpler.

- Application fields
  - Area surveillance and monitoring
    - military bases and installations
      - security improvement in exercise areas
      - mine field replacement
      - confirm reconnaissance information
      - command and control
      - toxic gas detection
    - crisis management
    - border guard
      - monitoring remote locations
      - unoccupied areas, etc.
    - harbors, air fields, industrial plants, nuclear plants, warehouses etc.
    - home security
    - animal tracking
    - exhibition areas
    - remote environmental control
      - forest fire detection
    - there are lots of potential application areas available !

- Who could benefit of this?
  - Commercial security companies
  - Police and frontier guard
  - Military
  - Industry
  - Citizen

What are the benefits of this?

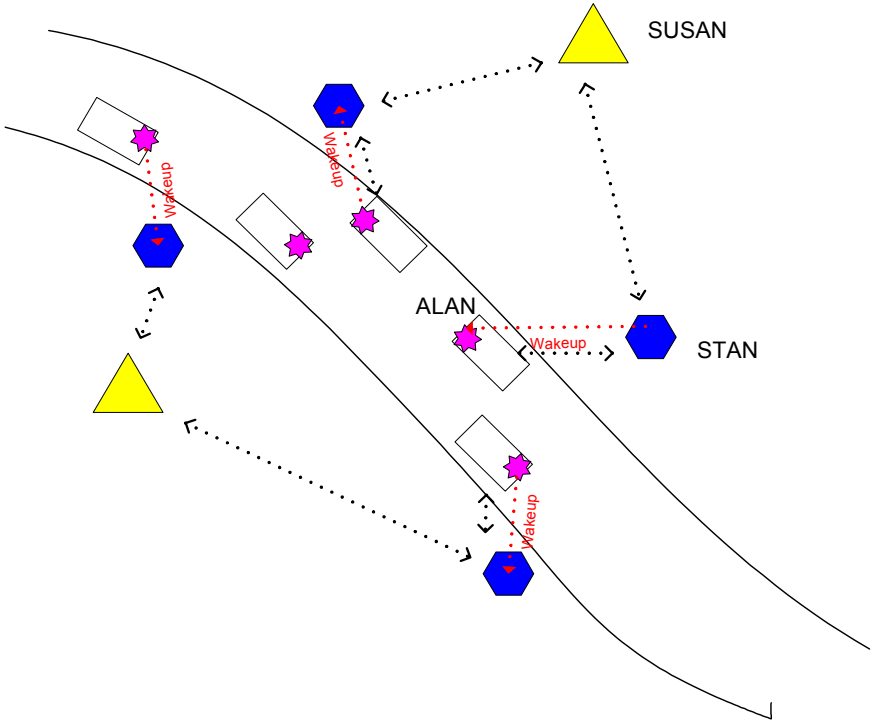
- Easy installation of sensors
  - majority of the sensor nodes have long endurance with their internal batteries
- Majority of the nodes are simple and hence cheap
- Small size of the nodes (in general)
- Controllability
  - sensor network can be ordered to increase or decrease its "alertness level" and battery consumption
- Data fusion from multiple sensors will increase the situational awareness
- Robustness due to the overlapping monitoring zones
- Independent network adaptation
- Event based wake-up reduces the latency that is based on TDMA based wake-ups

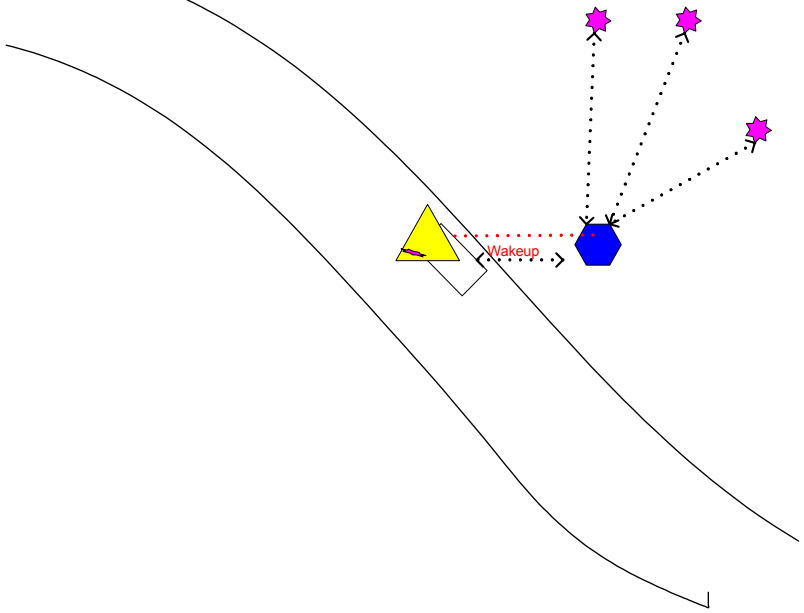
- Monitoring areas do not need to be circular, arbitrary shaped surveillance areas are possible
- Same device could also include multiple hierarchical levels
  - ALAN + STAN nodes
  - STAN + SUSAN nodes
  - ALAN+STAN+SUSAN nodes
- Multihop ad hoc routing is supported to extend the area and confirm the passage of the stimulus and improve the robustness of the network
- Transmitted data packet should include information about time and position originated by the event
  - identify individual events
- SUSAN+SUSAN handover for event tracking
  - handovers should include event history, e.g, track information and possible identification of the target

- Challenges:
  - Event based wake-ups
  - MAC protocol for wake-ups
  - How to wake a sleeping node without any timing information?
  - Implementation

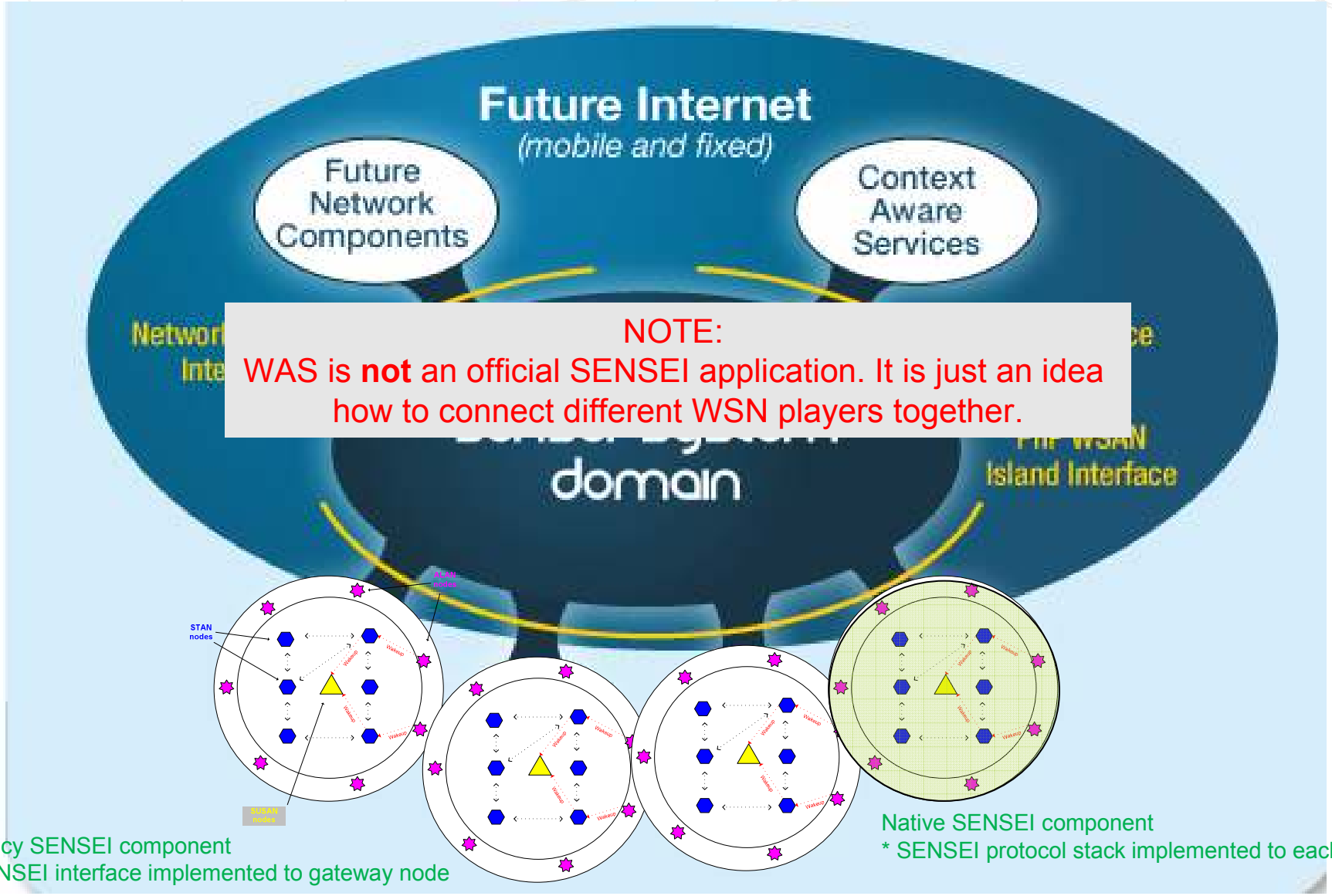
Application examples

- Traffic information delivery system





Possible WAS connection to the outside world



Legacy SENSEI component
* SENSEI interface implemented to gateway node

Native SENSEI component
* SENSEI protocol stack implemented to each node

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