Laurea Magistrale in Ingegneria Informatica
PROGETTAZIONE E SVILUPPO DI UN SISTEMA CROMOTERAPICO MEDIANTE UNA RETE DI SENSORI WIRELESS

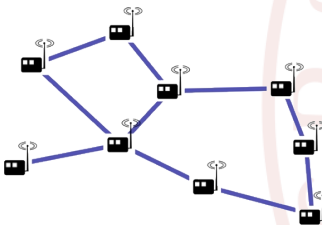Laureando: **Massimo Marra**
Relatore: Ch.mo Prof. **Luca Schenato**

Dipartimento di Ingegneria dell'Informazione
Università degli Studi di Padova

Padova, 7 Dicembre, 2010
Anno Accademico 2010/2011

Objectives

Motivation and goals

- **Soft real-time** chromotherapy application
- **Real time** generation of the **color sequence**
- **Interaction** with the **user**

State of the art - WSN

- Wireless Sensors ($\sim 10^2$-10^3)
- Small size
- Mobility
- Low cost and maintenance
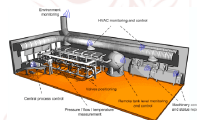- Ad-hoc network for environment monitoring

multihop
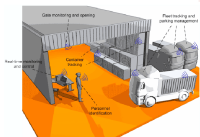

Application fields:

Environment control

Monitoring of industrial equipment

Indoor localization and Tracking

Health Care Applications

State of the art - Chromotherapy devices

Devices on the market

- All wired
- Centralized
- Poor coverage remote controller

Problematics and contribution

Problematics

- Coordination of the nodes
- Low complexity clock synchronization
- Communication of the real-time sequence across the WSN
- Reliability
- Fast colors change
- Coexistence of more than one WSN chromotherapy system
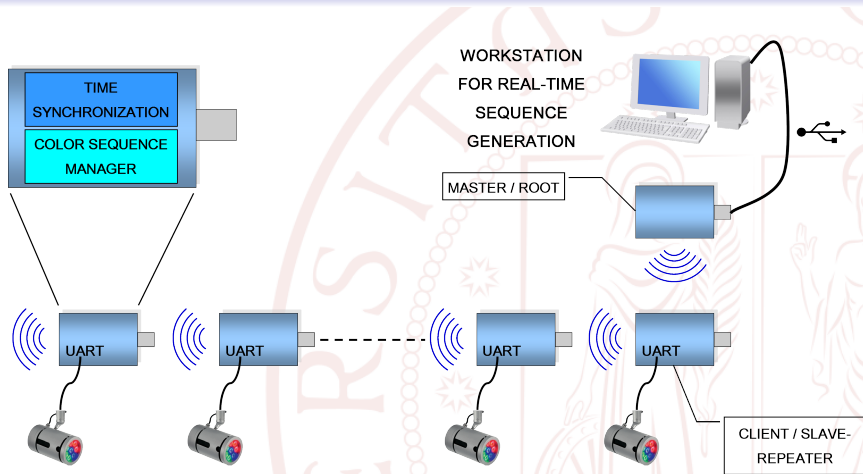
Problematics and contribution

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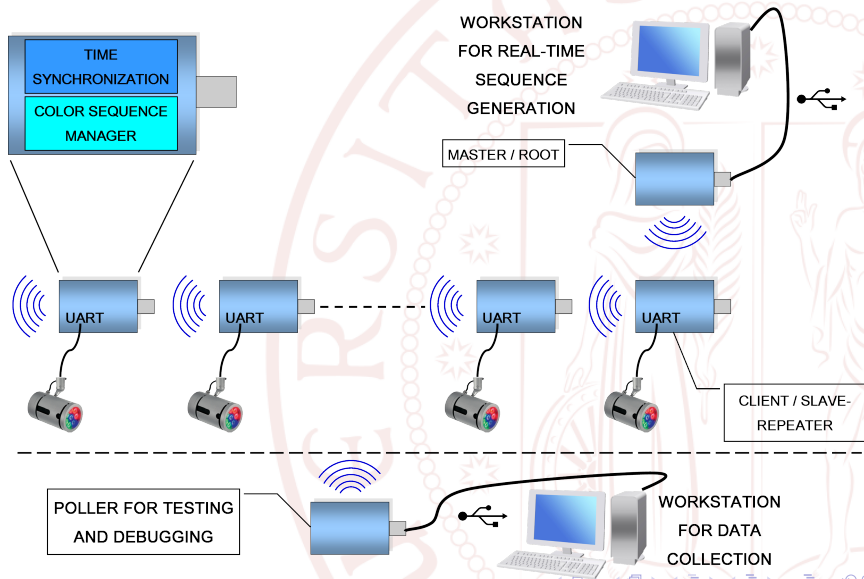- Coexistence of more than one WSN chromotherapy system

Contributions

- Development of adaptive **overlay-based** synchronization algorithm
- Development of **real-time color sequence** deployment
- Implementation of the complete system

Introduction
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SYSTEM ARCHITECTURE

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SYSTEM ARCHITECTURE

Overlay-based synchronization algorithm

Many synchronization algorithms for WSN

- FTSP
- RBS
- Solis et al. Algorithm
- ...
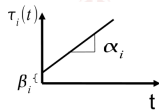
$$\tau_i(t) = \underbrace{\alpha_i}_{\text{Drift}} t + \underbrace{\beta_i}_{\text{Offset}}$$

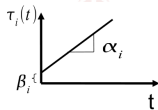# Overlay-based synchronization algorithm
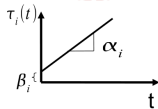
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$$\tau_i(t) = \alpha_i t + \beta_i$$

Drift   Offset

Simplified version: offset compensation

$$\widehat{\tau}_i^+ = \rho\widehat{\tau}_i + (1 - \rho)\widehat{\tau}_j = \widehat{\tau}_i + (1 - \rho)(\widehat{\tau}_j - \widehat{\tau}_i)$$

where $\rho \in (0, 1]$ tuning parameter

Overlay-based synchronization algorithm

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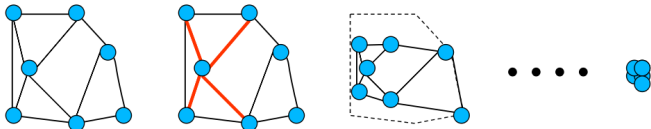$$\tau_i(t) = \alpha_i t + \beta_i$$

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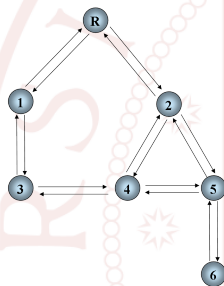
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Network configuration of O-b algorithm
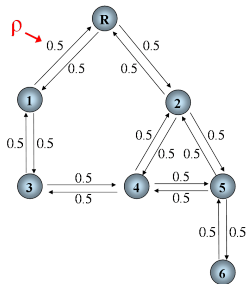
$$\widehat{\tau}_i^+ = \rho\widehat{\tau}_i + (1 - \rho)\widehat{\tau}_j$$
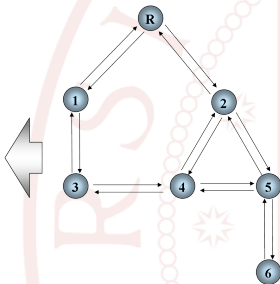
NETWORK

Network configuration of O-b algorithm

$$\widehat{\tau}_i^+ = \rho\widehat{\tau}_i + (1-\rho)\widehat{\tau}_j$$
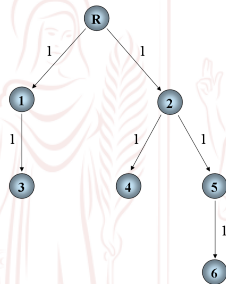

FULLY DISTRIBUTED

NETWORK

FULLY HIERARCHICAL

A. Slow convergence
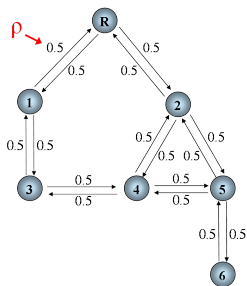
B. Worst steady state error

C. Robust to node failure

A. Fast convergence

B. Best steady state error

C. Fragile to node failure

Network configuration of O-b algorithm

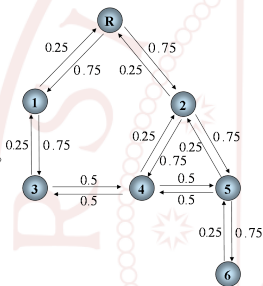$$\widehat{\tau}_i^+ = \rho\widehat{\tau}_i + (1 - \rho)\widehat{\tau}_j$$
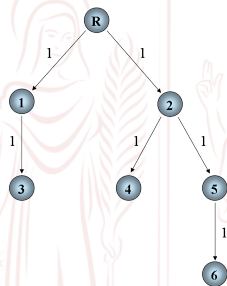

FULLY DISTRIBUTED **SOFT-HIERARCHY** **FULLY HIERARCHICAL**

A. Slow convergence

B. Worst steady state error

C. Robust to node failure

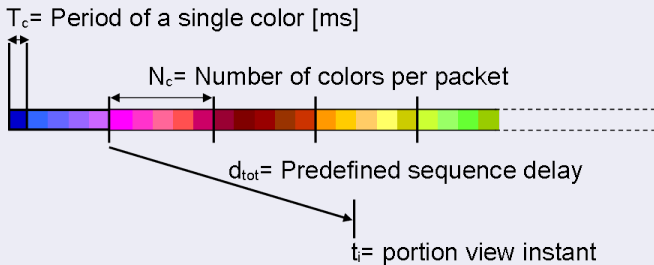A. Fast convergence

B. Small steady state error

C. Robust to node failure

D. Adaptive

A. Fast convergence

B. Best steady state error

C. Fragile to node failure

The color sequence communication
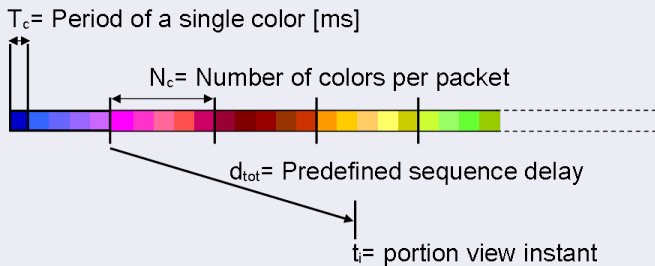
Real-time sequence generation

T_c= Period of a single color [ms]

N_c= Number of colors per packet

d_{tot}= Predefined sequence delay

t_i= portion view instant

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The color sequence communication

Real-time sequence generation

T_c= Period of a single color [ms]

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d_{tot}= Predefined sequence delay

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Communication protocol

- Flooding
- Random delay forwarding
- Double retransmission

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Example of sequence portion dissemination

FLOODING COMMUNICATION PROCESS

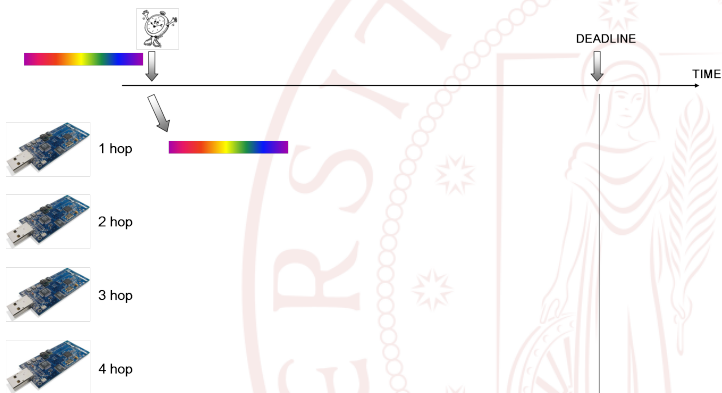PREDEFINED SEQUENCE DELAY

DEADLINE

TIME

1 hop

2 hop

3 hop

4 hop

GENERATION OF A SEQUENCE PORTION DONE
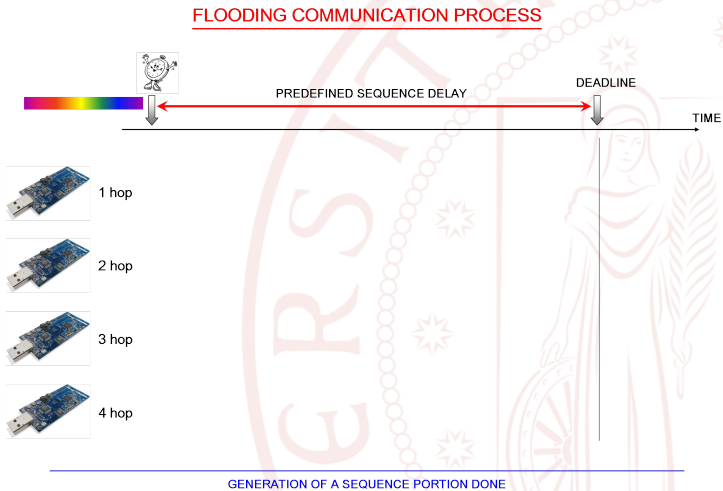
Example of sequence portion dissemination
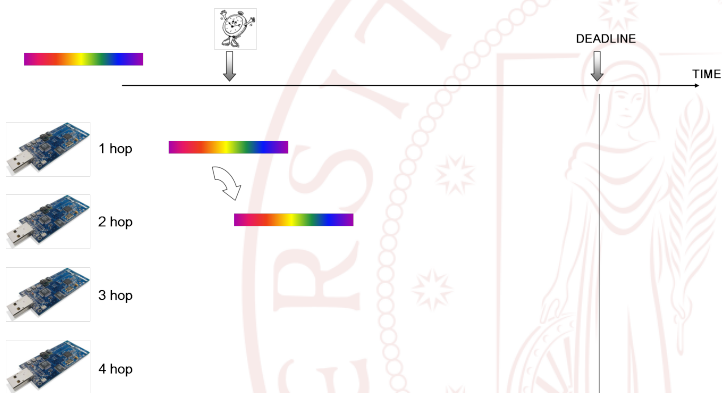

FLOODING COMMUNICATION PROCESS

THE MASTER SENDS THE PORTION AND THE DEADLINE TO ITS NEIGHBORS
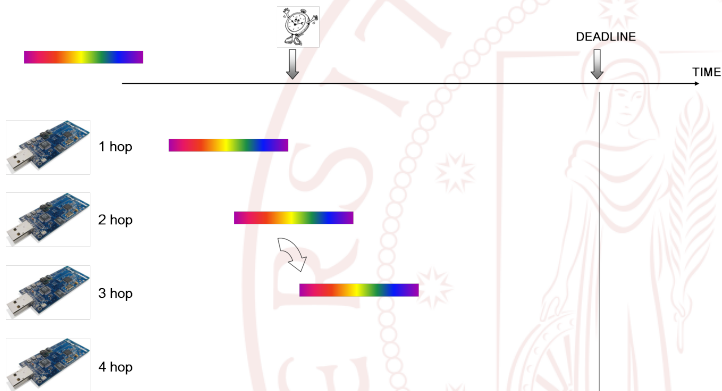
Example of sequence portion dissemination

FLOODING COMMUNICATION PROCESS

DEADLINE

TIME

1 hop

2 hop

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THE PORTION AND ITS DEADLINE ARE FORWARDED FROM HOP 1 TO HOP 2

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Example of sequence portion dissemination

FLOODING COMMUNICATION PROCESS

Example of sequence portion dissemination

FLOODING COMMUNICATION PROCESS

DEADLINE

TIME

1 hop

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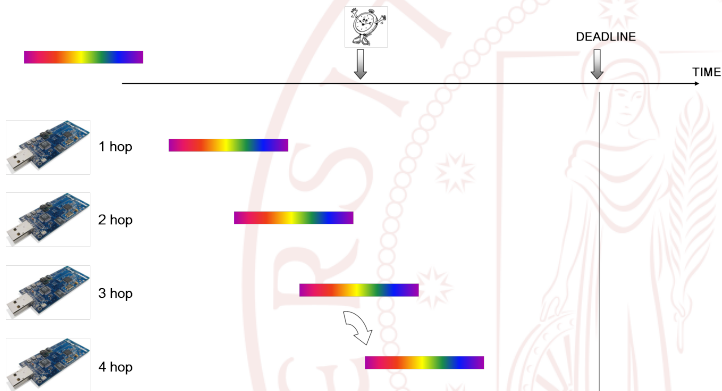
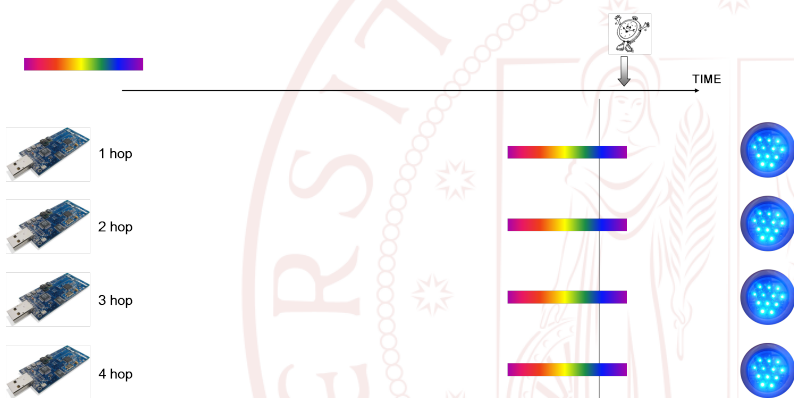THE PORTION AND ITS DEADLINE ARE COMMUNICATED TO ALL THE WSN NODES

Example of sequence portion dissemination
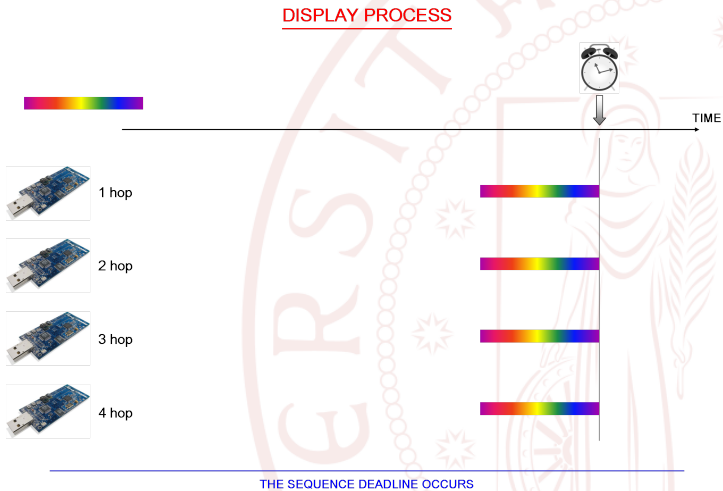
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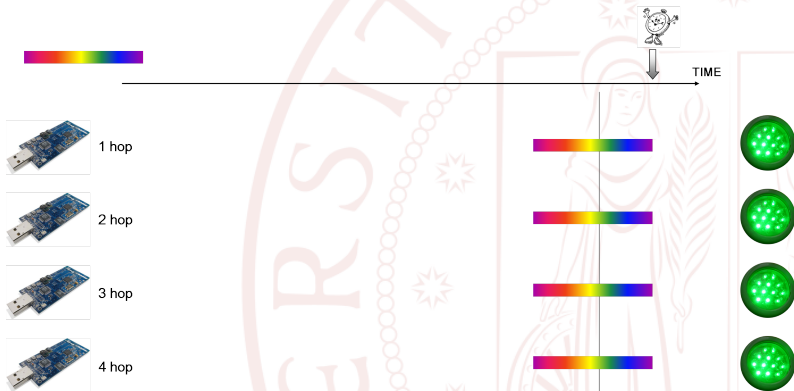# Example of sequence portion dissemination

DISPLAY PROCESS

TIME

1 hop

2 hop

3 hop

4 hop

THE SYNCHRONIZED NODES SCAN THE SEQUENCE IN A COORDINATED MANNER

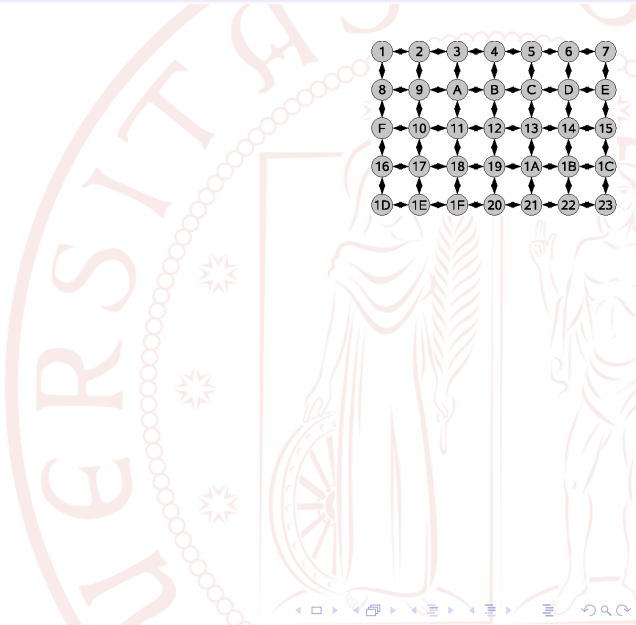# Example of sequence portion dissemination

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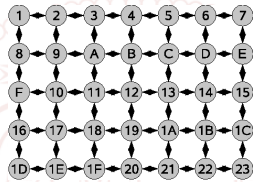# Example of sequence portion dissemination

DISPLAY PROCESS

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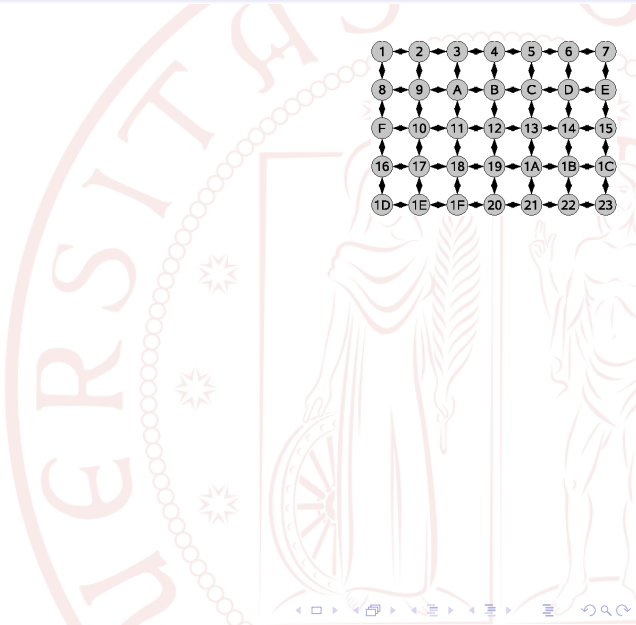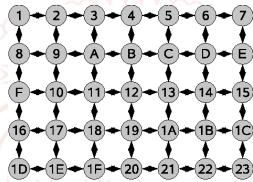THE SYNCHRONIZED NODES SCAN THE SEQUENCE IN A COORDINATED MANNER
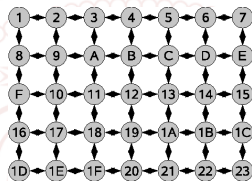
Synchronization Tests

- Grid network

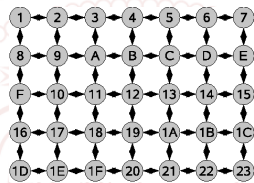## Synchronization Tests

- Grid network
- 35 nodes

Synchronization Tests

- Grid network
- 35 nodes
- 10 hops
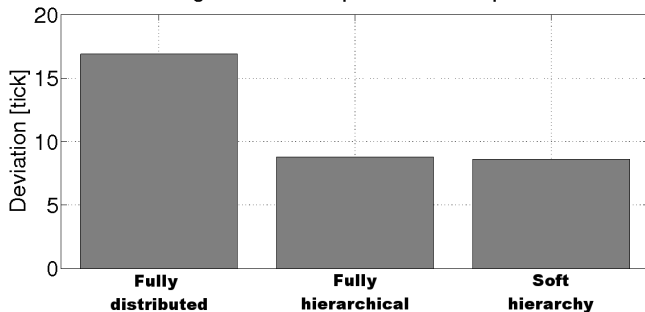
Synchronization Tests

- Grid network
- 35 nodes
- 10 hops
- Synchronization period 30 sec

Average of the max pairwise error per Test

1 tick = 30 μs

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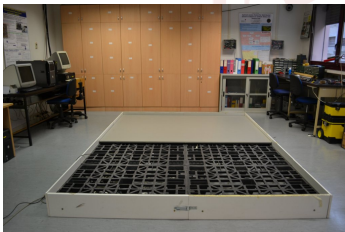○○

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Test results of the chromotherapy system

Results

- Double retransmission is necessary

← The test bed

Test results of the chromotherapy system

Results

- Double retransmission is necessary
- $r_c = 5Hz$ easy achievable

$\leftarrow$ The test bed

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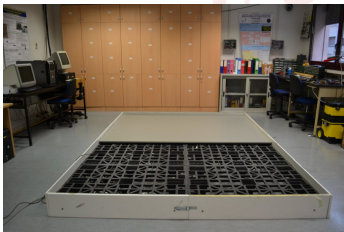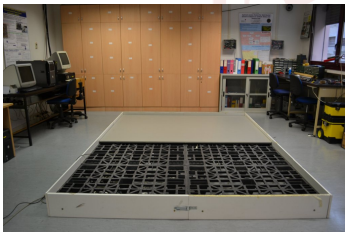- Low packet loss ($\ll 1\%$) up to 4/5 hops (50/100m indoor)

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Test results of the chromotherapy system

Results

- Double retransmission is necessary
- $r_c = 5Hz$ easy achievable
- Low packet loss ($\ll 1\%$) up to 4/5 hops (50/100m indoor)
- Packet period $\geqslant 2$ sec

$\leftarrow$ The test bed

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Test results of the chromotherapy system

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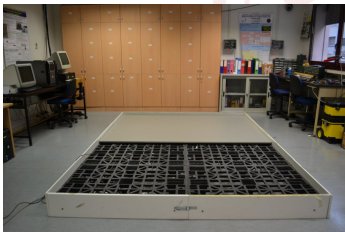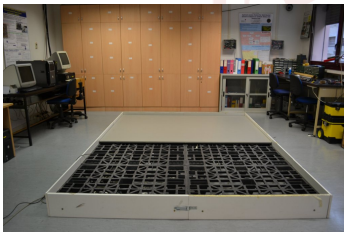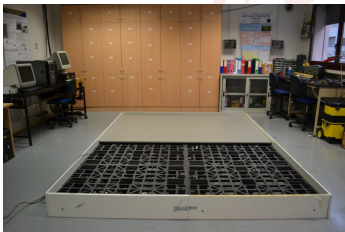- Predefined sequence delay $\geqslant 1$ sec

$\leftarrow$ The test bed

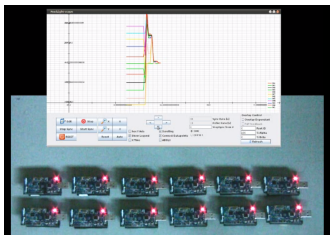# Test results of the chromotherapy system

Results

- Double retransmission is necessary
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- Packet period $\geqslant 2$ sec
- Predefined sequence delay $\geqslant 1$ sec
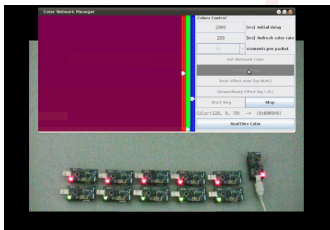- Color jitter < 1 ms

$\leftarrow$ The test bed

Videos

Overlay-based synchronization protocol

Chromotherapy effect simulation

Conclusions and further developments

Conclusions

- Adaptive and high performance synchronization protocol
  - error $\leqslant 1$ ms
  - 100 nodes
  - synchronization period 30 sec

Conclusions and further developments

Conclusions

- Adaptive and high performance synchronization protocol
    - error $\leqslant 1$ ms
    - 100 nodes
    - synchronization period 30 sec
- High fidelity Chromotherapy system
    - up to 4/5 hops
    - $r_c = 5Hz$
    - Predefined delay $\geqslant 1$ sec
    - Sequence change 2 sec

Conclusions and further developments

Conclusions

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    - error $\leqslant 1$ ms
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    - up to 4/5 hops
    - $r_c = 5Hz$
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- Implementation of the entire architecture

Conclusions and further developments

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  - error $\leqslant 1$ ms
  - 100 nodes
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- High fidelity Chromotherapy system
  - up to 4/5 hops
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  - Sequence change 2 sec
- Implementation of the entire architecture

further developments

- Leader election
- Event-based sequence generation (movements or sounds)
- Sequence compression

THANKS FOR THE ATTENTION