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Precise Location Tracking System based on Time Difference of Arrival over LR-WPAN

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Introduction

OUR APPROACH : TDOA-based LTS over LR-WPAN

- Location estimation by **Time Difference Of Arrival**
- Strict time synchronization between LTS readers
- Precise time measurement for a signal of tags
- Design of robust and reliable LTS reader
- Design of low power operation for the tag

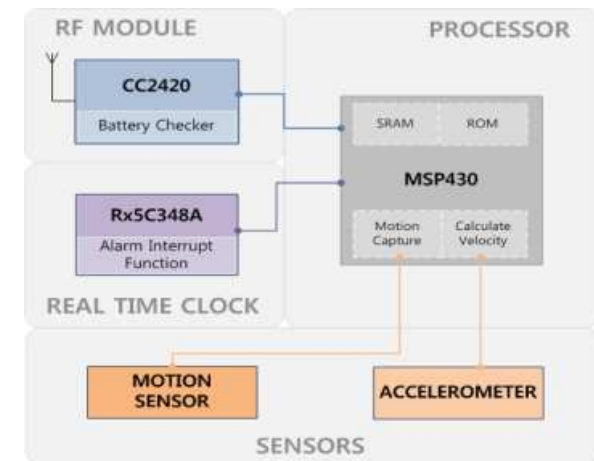
APPLICATIONS

- Assets management
- Job order tracking
- Container management
- Patient management
- Silver town monitoring
- Dangerous substance management

Location Tracking System : Implementation

✚ LTS Tag

- Processor : TI MSP430
- RF transceiver : CC2420 (IEEE 802.15.4)
- Communication range : Up to 200m
- Low power operation
 - ▶ Adaptive blink control using motion sensor
 - ▶ Energy efficient operation using RTC



Location Tracking System : Implementation

LTS Reader

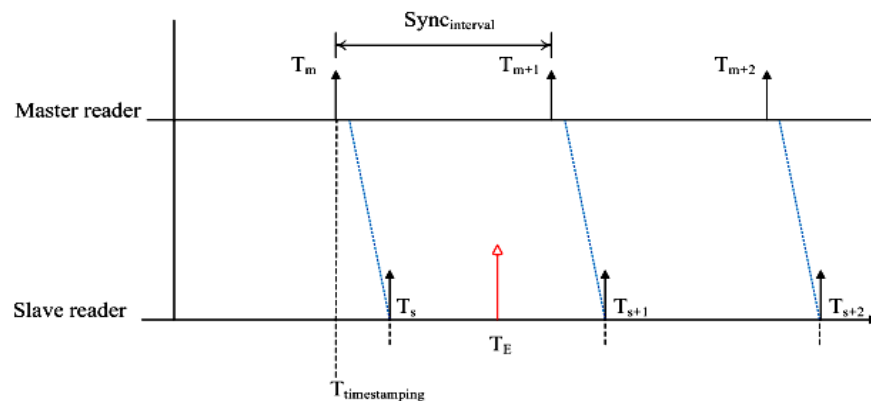
- Main processor : Intel PXA255 (400MHz)
- Time processing unit : Altera Cyclone II FPGA
 - ▶ Accurate time synchronization
 - ▶ Precise time measurement for signal collection
 - ▶ Clock granularity : 6.25ns at 160MHz
- Dual RF module : CC2420 (IEEE 802.15.4)
 - ▶ Time synchronization between readers
 - ▶ Tag collection for locating and tracking
- 10/100Mbps Ethernet UDP/TCP communication



Location Tracking System : Operation

✚ Time Synchronization on IEEE 802.15.4 radio

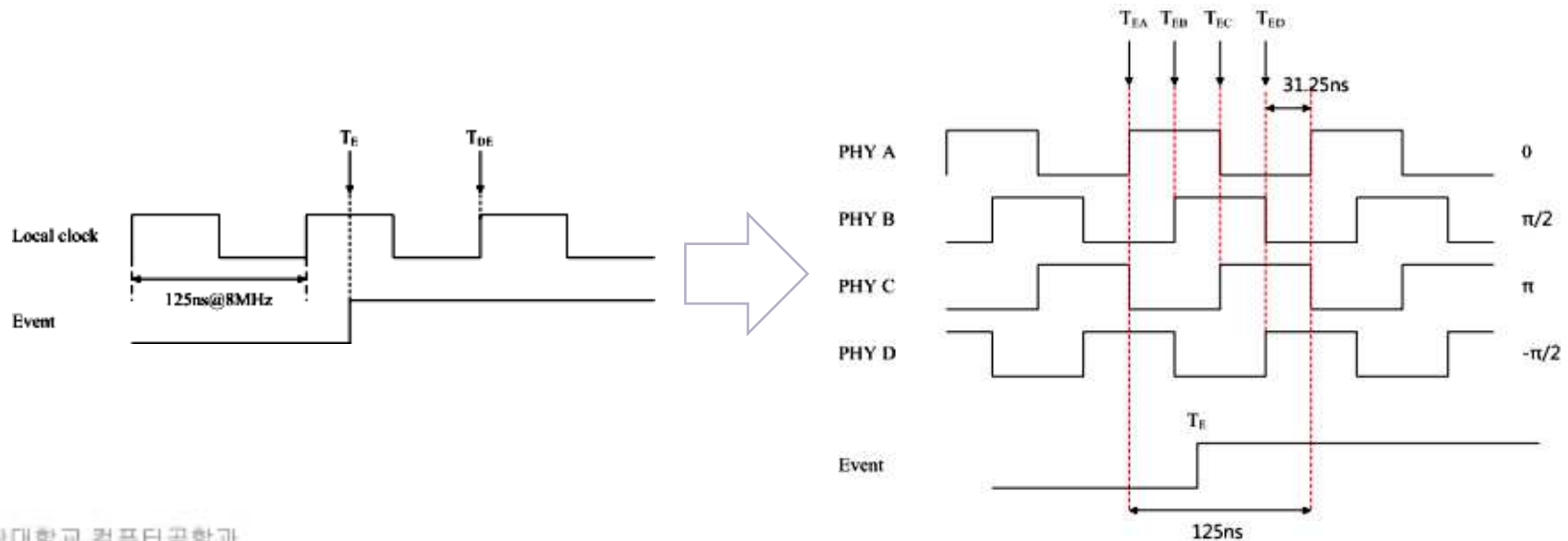
- Time synchronization by message exchange
- Periodic transmission for drift correction
- Uncertainty elimination of a protocol stack
 - ▶ hardware assistant time stamping by FPGA at MII layer
- To overcome RF resolution (8Mchip/s)
 - ▶ Multi phase radio receiver (RF transceiver granularity : 125ns → 31.25ns)
- To overcome time representation error
 - ▶ Kalman filtering with the weighted average
- Time synchronization accuracy : within 5 nanoseconds



Location Tracking System : Operation

✚ Precise Time Measurement

- IEEE 802.15.4 compliant transceiver has 8Mchip/s
 - ▶ Uncertainty is max. 125ns
 - ▶ Affect time stamping of tag collection
 - ▶ Affect time stamping at time synchronization
- Granularity 125ns → 31.25ns
 - ▶ Using multiple receivers
 - ▶ Each receiver is sourced by the shifted phase clock of 90 degree
 - ▶ Earliest time stamping value is selected as event time



Location Tracking System : Operation

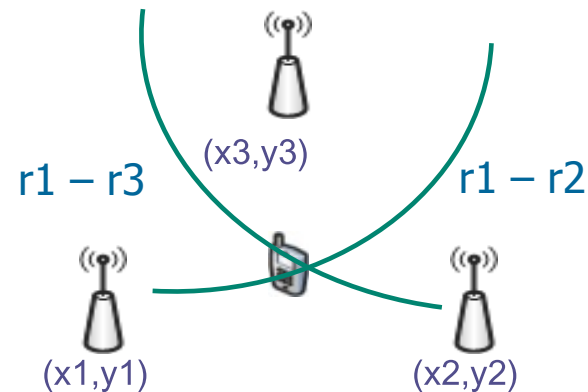
Localization

- The LTS engine determines tag location by calculating a time difference between readers in a spherical intersection(SX) manner based on the least square method.
- Let the coordinate of the tag be (x, y) and the reader i be (x_i, y_i) . The tag's location is determined as following.

$$r_i = [(x - x_i)^2 + (y - y_i)^2]^{\frac{1}{2}}$$

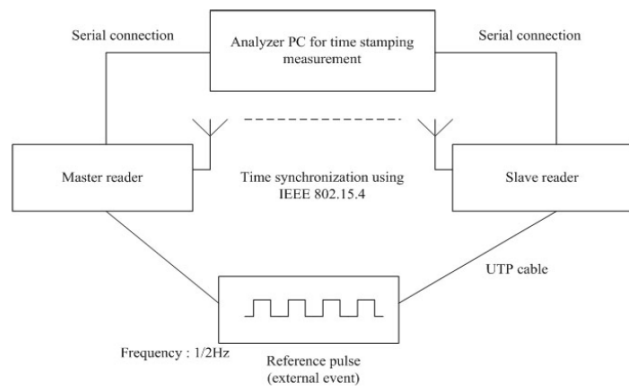
$$r_{ij} = r_i - r_j, \quad k_i = x_i^2 + y_i^2$$

$$(xy)^T = \frac{1}{2} \begin{pmatrix} x_j - x_1 & y_j - y_1 \\ \vdots & \vdots \\ x_j - x_n & y_j - y_n \end{pmatrix}^{-1} \left[\begin{pmatrix} k_j - k_1 + r_{1j}^2 \\ \vdots \\ k_j - k_n + r_{nj}^2 \end{pmatrix} + \begin{pmatrix} r_{1j}^2 \\ \vdots \\ r_{nj}^2 \end{pmatrix} \right]$$

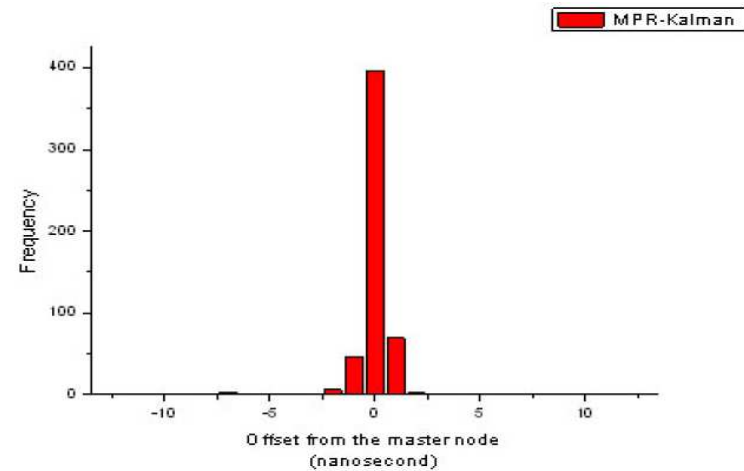


Location tracking system : Time synchronization

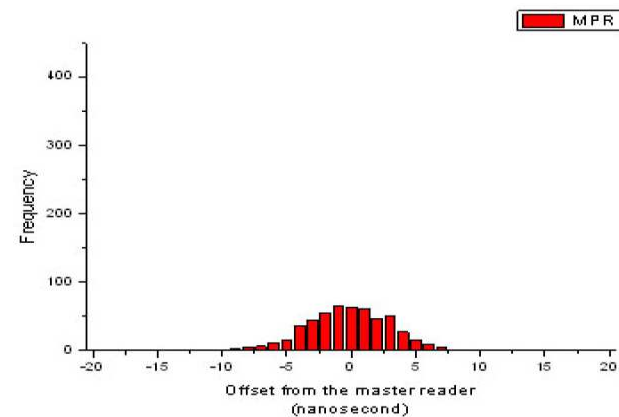
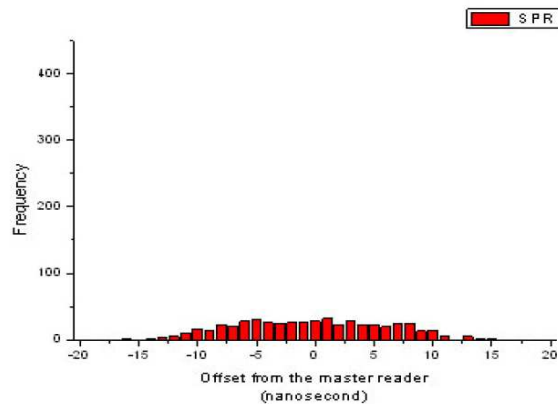
System setting



MPR with kalman filtering



SPR vs MPR



Location tracking system : Localization

System setting



Reader



Tag



Movement tracking

