On Developing Dependable Positioning

Christophe Pitrey
CEDRIC Laboratory
CNAM, France
Email: christophe.pitrey@cnam.fr

Francoise Sailhan
CEDRIC Laboratory
CNAM, France
Email: francoise.sailhan@cnam.fr

***Abstract*—Developing indoor positioning remains challenging, especially when we consider an emergency and disaster scenario wherein positioning infrastructures fail. In this case the objective consist in providing to first rescuers (firefighters) robust and reliable positioning under harsh conditions. Toward this goal, we present a navigation system, then, we survey the class of faults that threaten this system along with possible ways of handling it.**

I. Position and Navigation

The proposed positioning system makes use of active and contact-less Radio-Frequency IDentification (RFID): firefighters are equipped with RFID readers while RFID tags are disseminated in the building so as to serve as anchors. The pair-wise distance separating the reader to an anchor, is estimated based-on the Received Signal Strength (RSS)[1][2]. The resulting distance is used to multilaterate the position of the reader. Given that the signal may be perturbated (§1), successive RSS measurements are sanitized, i.e., filtered: infrequent values and outliers are removed so as to ensure that the largest quorum of consistent values is selected. Then, based on the measurements provided by m tags, the position (x_p, y_p) is approximated by multilateration. Multi-laterating consists in determining the intersection of m circles; each circle $\mathscr{C}i$ being centered on an anchor and characterized by a radius corresponding to the measured RSS:

$$(x_p - x_i)^2 + (y_p - y_i)^2 = RSS_i^2 \quad (1)$$

with (x_i, y_i) defining the anchor's coordinates. Multilateration can be seen as resolving a least-squared problem, i.e., finding the

$$\min_{(x_p,y_p)} \sum_{i=1}^{m} (x_p - x_i)^2 + (y_p - y_i)^2 = RSS_i^2 \quad (2)$$

Nevertheless, as illustred in Figure 1, the uncertainty resulting from RSS measurements implies that Equation 2 is not solved on a single point given by (x_p, y_p). Solving such a problem involves an increased complexity which is simplified using a two-steps approximated geometric process. First, rather than relying on the m tags that are in transmission range, the 3 nearest tags are selected. This choice is motivated by the fact that the RSS measurement accuracy decreases as the distance increases (logarithmic precision). Then, a central estimated point Pe is obtained by the intersection of two lines, each one passing through two points of intersection between two circles. Futhermore, 3 intersections points $(I1, I2, I3)$ nearest the point Pe are retained. Each point corresponding to a triangular vertices (Figure 2). Second, the central position P is determinated by the intersection of the medians of the triangle given by the 3 vertices. The resulting coordinates are further transmitted to one another so as to be displayed. For this purpose, a multi-players (multi-firefighters) game-enabled displaying platform (Game Maker[1]) is utilized. Overall, such a navigation system is subject to a variety of threats ranging from signal distortion (§2), trilateration (§3), transmission and distribution (§4), each of those requiring a specific handling.

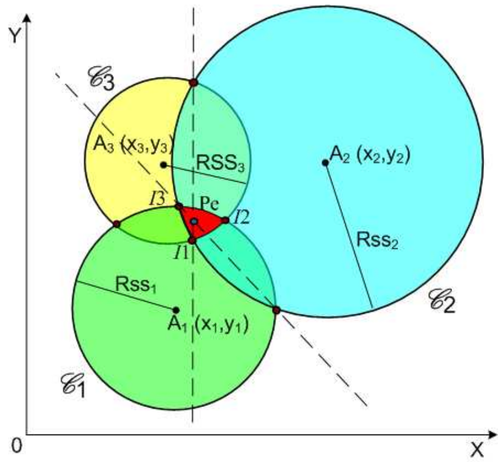

Fig. 1. *Trilateration.*

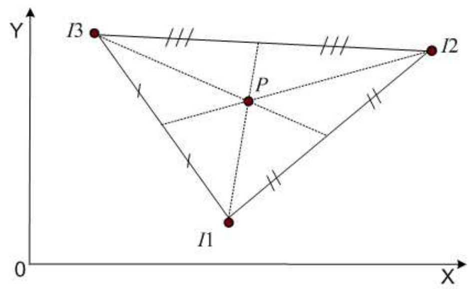

Fig. 2. *Central position of a triangle.*

II. Radio Wave

The signal (and hence the RSS measurements) are impacted by a variety of distortions. More particularly, an antenna does not radiate uniformly and the propagation of the signal differs depending on the angles of emission and arrival of the signal. In addition, this signal is subject to any interference created by any electrical equipment operating on, or around, the spectrum (recall that the operational RFID spectrum is unlicensed and hence not protected). Moreover, radio waves suffer from propagation, reflection and absorption together

[1] http://www.yoyogames.com/gamemaker

mainly due to the presence of obstacles and reverberating surfaces in the building frame e.g., reinforced concrete, metal... Note that human are constituted of 80% of water and hence constitutes a strong reflector to radio signal. These phenomena impact the strength and quality of the received signal which in turn affects the RSS measurement of one another positioning system. Additional disaster-specific parameters including, variable atmospheric conditions (e.g., thermal, brightness) and presence of hydrometeors (e.g., vapor, rain drop) affect the signal characteristic. Overall, the aforementioned faults can be classified as static or time-varying. The former mainly results from (i) the antenna irregularities and (ii) the physical arrangement of the obstacles. To tackle this issue, external and omni-directional antenna should be preferred and fingerprinting should be applied. This consists in recording the RSS at each location. Then, RSS is measured so that the best-matching RSS that were previously recorded, is identified and its related location deducted. During a disaster, time-varying faults are mainly unpredictable and depend on the operational environment. This advocates for providing sensor-enabled, context-aware and self-healing positioning.

III. TRILATERATION

A multi-lateration-enabled 2D-positioning of a firefighter requires to place anchors in a way which ensures the appropriate coverage of the geographical area and the significant redundancy. In practice, at least m non-collinear anchors should be in transmission range with a firefighter. Such a staggered placement necessitates careful network planning, i.e., covering, identifying, positioning anchors and recording the related information. Here, a manual acquisition may lead to a multi-lateration failure unless pre-checking (e.g., research of duplicate records) and control mechanism (consisting in e.g., verifying that the recorded tags' characteristics are actually consistent with the observed positions) are performed. Despite these mechanisms, full coverage cannot be assumed during a disaster: anchors are expected to fail as the sinister evolves. In addition, power-supply failures are observed (battery-powered tags and readers may still fail in spite of a low-energy consuming and an automatic alert triggering in case of low-remaining energy).

IV. TRANSMISSION & DISTRIBUTION

Positioning information is intended to be shared with any stakeholder. However such information may be either corrupted or lost at the source that generates it, during its transit, or at the receiver (§2). So, the use of a shared frequency band implies that other emitters interfere. This necessitates either providing pseudo-random spectral frequency hopping or listening before talking process. It may also happen transmission errors, packet de-sequencing, disconnections lead to message/packet loss and disconnections resulting from a node failure [3]. To resist to these former, one should use reliable protocol, e.g., Transmission Control Protocol (TCP) and to verify data integrity, and re-establish connections. The system should be tolerant of faults and it must correct automatically these faults. It should be always available and operational due to program or memory corruption and then prevent the spread of this fault to the other elements. It will also be attentive that each user uses the same recorded tags and play the same Game Maker versions to avoid an erroneous or different display. All these fault-tolerant mechanisms should hence be provided as part of the positioning system.

V. CONCLUSION

We presented an indoor RFID-based positioning system, easy to use, involving a low financial cost. This system displays the position of a firefighter based on trilateration calculations (RSS measurements of anchors in range). We have implemented a prototype and during our testing some approximations on positioning were revealed. In spite of all efforts realized, guarantee the survivability of such a positioning system still remains particularly challenging. Indeed our system is subject to various faults: The hardware design, the radio interference, the building frame and atmospheric evolution during a disaster will cause a variety of threats, which influence trilateration and disturb the exact display position of a firefighter. The transmission of information between the participants should be reliable, resistant and tolerant of faults to prevent disconnection and to guarantee the system availability. We must therefore create a policy test of our system that verifies the coverage and placement of each anchor. These tests check also human error input and the duplicated records. So, in order to maintain the confidence of firefighters to the positioning system, it's of prime necessity to display the measurement uncertainty, degree of accuracy/precision (precision circle drawn around the firefighter) and degree of confidence. It is vital to know the robustness of our system because here the lives of firefighters are at risk. Hence, we plan to study the dependability of our indoor positioning system, by developing an injection fault solution. Through this tool we will be able to realize the scenarios for modeling errors or interferences and to check their impact on the functioning of the system. The advantage of this system is that it is replicable as many times as you want each scenario to test the robustness of our localization solution.

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Christophe PITREY received his engineer degrees from the *Conservatoire National des Arts et Métiers* (CNAM, Paris, France) in 2010. He is currently a PhD student at CEDRIC Laboratory of CNAM. His PhD topic is focused on faults injection in Wireless Sensor Networks. Christophe has worked about 10 years at GEMALTO in particular on the industrialization of electronic payment terminals (production monitoring, testability, security software and hardware of TPE). Prior to this appointment, he was a technician at STENTOFON COMMUNICATION responsible for installation, repair and advice on radio paging systems.