MS assisted positioning

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Venue:
IEEE 802.16m-08/033 Call for Comments and Contributions on Project 802.16m System Description Document (SDD) for Session 57, on the topic of “PHY & MAC aspects of Location Services”.

Base Contribution:
None

Purpose:
For discussion and adoption as part of LBS section.

Other MSs may be helpful

- In a TDD system, it is possible that “other MSs” can help BS to position a MSa with insufficient # of FL pilots
- Other MSs:
  - MS with GPS receiver
  - MS with multiple antenna which more likely can resolve multiple FL pilots
  - MS receives a FL pilot which was not reported by MSa
  - Fixed MS

Network asks helps form other MSs

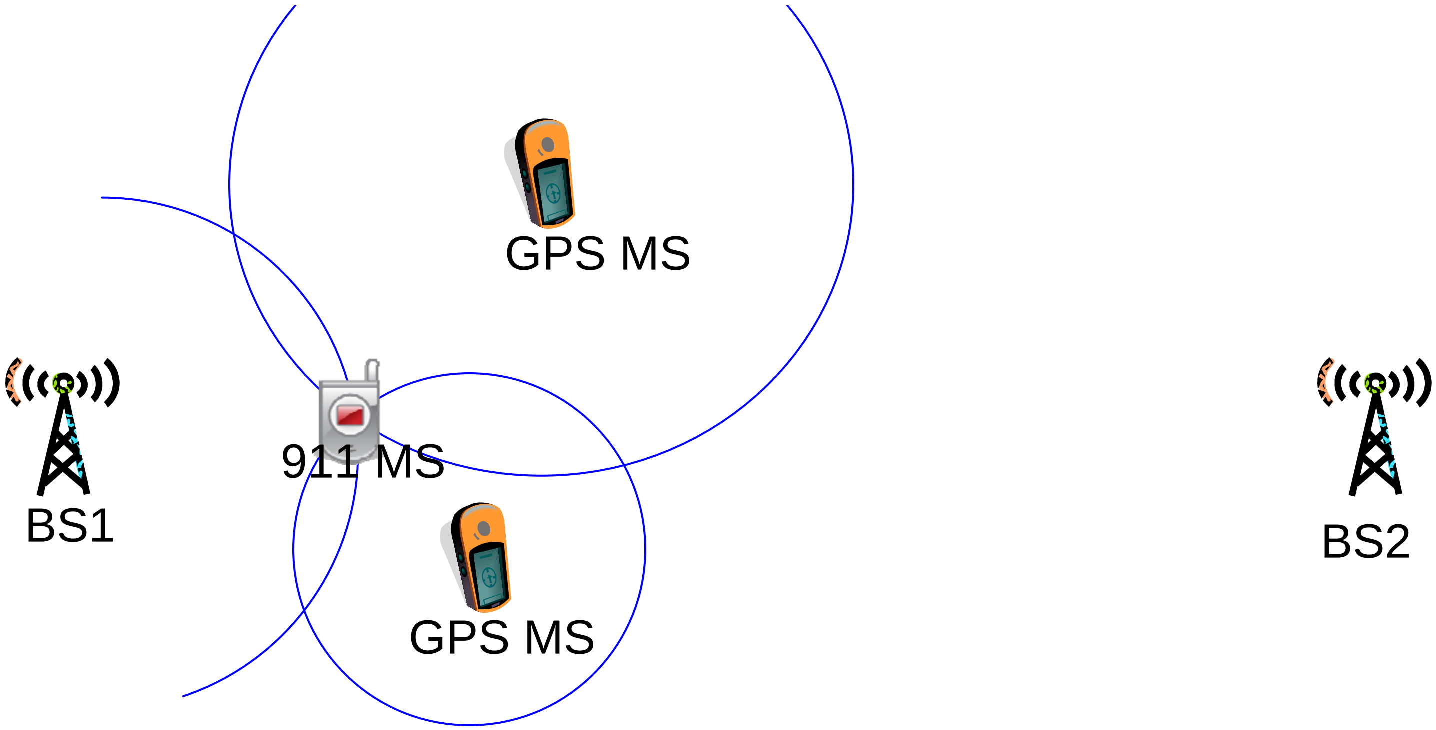
- GPS-capable MS are assigned to a particular paging interval
- If BS receives AFLT measurement from MSa with insufficient data, it can send a reserved ranging allocation to MSa, broadcasted at the beginning of the GPS-capable MS paging interval
  - The allocation block in control channel also indicates:
    - Quality threshold of MSa ranging signal
    - Pilots reported by MSa

Make idle MS helpful (1/2)

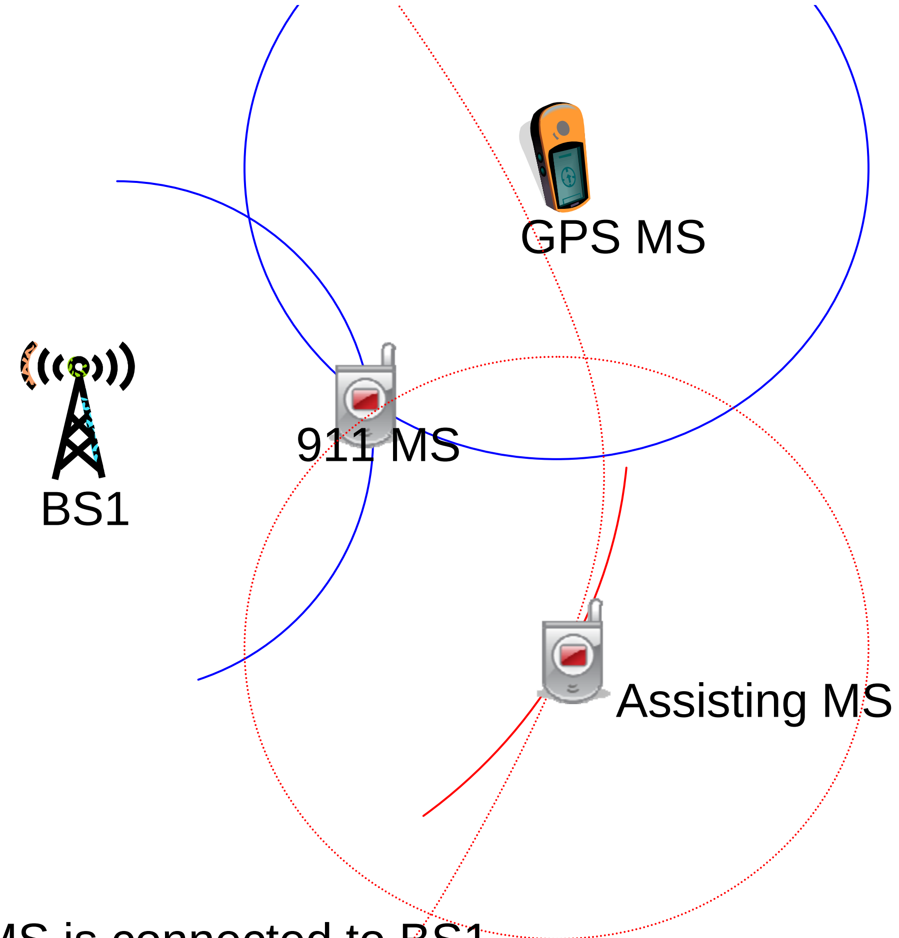
- When GPS MS monitors its page, it also receives this resource assignment block (to MSa) in the control channel
  - GPS mobile will listen to the assigned code, at assigned sub-channels and time slot to MSa
  - If it receives MSa ranging code with certain quality, it accesses BS to report
    - Its own GPS location
    - The time offset between its own reference time and the arrival of MSa signal
    - Measured signal strength
    - Time offset measurement, and signal strength measurement may be omitted based on positioning requirements

Make idle MS helpful (2/2)

- If no sufficient # of GPS MS responds, BS can broadcast the ranging assignment at other MS's paging time
  - mobile may listen to the assigned code, at assigned sub-channels and time slot to MSa
  - If it receives MSa ranging code with certain quality, and it observes at least a pilot not measured by MSa, it accesses BS to report
    - Its FL pilots phase measurement
    - The time offset between its own reference time and the arrival of MSa signal



- 911 MS is connected to BS1
- 911 MS (w/o GPS) only observes one sector pilot
- BS1 allocates ranging slot/code for the 911 MS and send this info when GPS capable MS wakes up for their pages
- GPS capable MS's report their locations and timing info of 911 MS if they have received 911 MS ranging with certain quality
- Fast moving GPS-capable MS should not respond



- 911 MS is connected to BS1
- 911 MS (w/o GPS) only observes one sector pilot
- BS1 allocates ranging slot/code for the 911 MS and send this info when GPS capable MS wakes up for their pages, and at other paging opportunities
- The GPS capable MS's reports its location and timing info of 911 MS if it has received 911 MS ranging with certain quality
- Non-GPS-Capable MS may report its measurement of 911 MS if it has received 911 MS ranging with certain quality, and it has measurements of pilots other than BS1

Non-E911 Usage Scenario

- In a big indoor shopping mall, it will be very useful if a mobile user can find a store. Also, stores can provide advertisements to encourage users to visit the stores.
- GPS is not available indoor, but there will be GPS-capable mobiles or mobile relays outside the mall but close to the mall.

Proposed Text

- MS shall signal its GPS capabilities when negotiating basic capabilities in network entry
- BS may assign a ranging opportunity to the positioned MS. The assignment may include the FL pilots which have already been reported by the MS, and a signal quality threshold
- BS should assign a set of GPS-capable mobiles with the same paging offset and intervals. Ranging assignments to the positioned MSs should be sent at the same time.
- MS which is aware of its location, and has received ranging signal from positioned MS above quality threshold, shall report to BS with information related to the received signal. The access delay of reporting can be randomized based on the assisting MS position and id’s
- MS which has received ranging signal from positioned MS above quality threshold, and has multiple FL pilot measurements, with at least one of them not included in pilots indicated in the ranging assignment to the positioned MS, should report to BS with information related to the received signal. The access delay of reporting can be randomized based on the assisting MS id’s

Analysis

Performance Analysis of “MS-assisted LBS” – a simplified analytical evaluation

Purpose
This is to examine how much gain the proposed scheme can achieve. This can be used as a (rough) evaluation result for 16m contribution, if needed.

Scope
For the sake of simplicity in analytical evaluation, we have the following assumptions.
In later section, we use “likelihood” of location estimation as a form of a function but formal definition of the “likelihood” is an interesting issue but beyond the scope

Remark: There are several things that must be clarified for performance analysis, which are also needed even for simulation. For simplicity’s sake, we introduced some simplifying assumptions.

Analytical Model and Underlying Assumptions

1. The layout of base stations (BSs) forms a hexagonal lattice in a flat region.
    a. A cell forms a hexagon.
    b. A triple of neighboring BSs forms a regular triangle.
    c. Example:

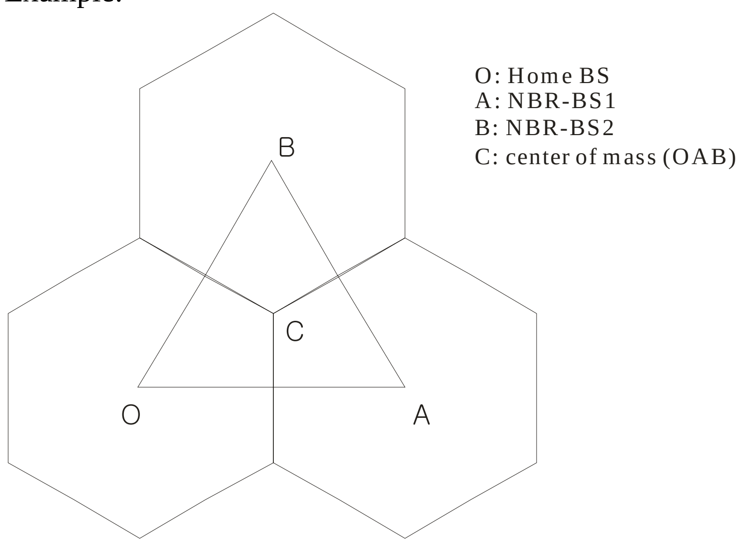


Fig. 1. Cell layout.

1. The geometry

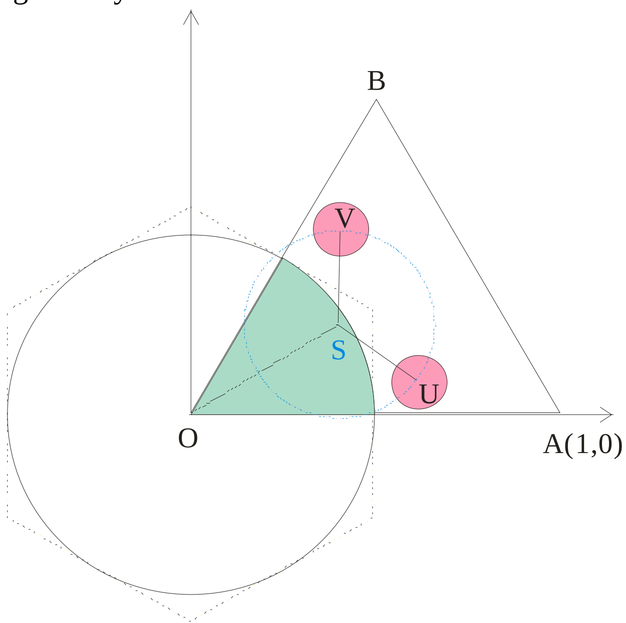


Fig. 2. Geometry of analytical model. Polar coordinate system. The radius of circle S is $L = \overline{SV} = \overline{SU}$. The radii of circles V and U are the same, say R, where $0 < R < \min\{1/\sqrt{\pi}, \sqrt{3}L\} < 1$. $\angle VSO = \angle OSU = \angle USV = 2\pi/3$.

a. Home BS: O(0,0)
b. NBR-BS1: A(1,0)
c. NBR-BS2: B($1, \pi/3$), i.e., ($1/2, \sqrt{3}/2$) in the Cartesian coordinate system.
d. The position of a target MS is denoted by point S(r,θ). Without loss of generality, we consider the green region for the possible position of a target MS.
e. Remark: we use the term "position" for analysis purpose only, which is not the estimated location of MS by the LBS mechanism employed.
f. The number of "GPS-MS's" within a unit area is ρ and they are evenly distributed within a unit area.
g. Definition 1: "reference point" is a unit reporting LBS-related parameter measurements to "Home BS". For example, in BS-only LBS mechanism, NBR-BS1 and NBR-BS2 are a "reference point", in the proposed mechanism, a "GPS-MS" is a reference point.
h. Definition 2: we define "distance-r" as max{distance between Home BS and reference point 1, distance between Home BS and reference point 2 }
i. We consider the case that, given L and R, if there exists (at least) one "GPS-MS" (i.e., GPS-capable MS) within the circle V and circle U, respectively, the proposed "MS-assisted LBS" mechanism can produce information for the "Home BS" so that the "Home BS" can predict the location of the target MS ("S" in Fig. 2) at a comparable error range that the BS-only LBS mechanism given that "distance-r" is the same.
j. We assume that a function, which maps "distance-r" to "estimation likelihood". $f(x), 0 < x < 1$.

Analysis

Let $P_V(L,R)$ denote the probability that (at least) one "GPS-MS" is available within the circle V. Similarly, we define $P_U(L,R)$.

For an MS at (r,θ), the probability that the propose mechanism can operate (as per the above assumptions) is given by

$$P_V(L,R)\cdot P_U(L,R)$$

where it can be modeled with Binomial approximation (i.e., using Binomial distribution with parameter (ρ , πR^2). Here, ρ is considered as the number of "GPS-MS's" within a unit area and πR^2 is the probability that an arbitrary "GPS-MS" is located within a small circle of radius R (i.e., $(\pi\cdot R^2)/(1^2)=\pi R^2<1$).

Then the "likelihood" is given by

$$\begin{aligned} &g(r)\\ &= f(R+\sqrt{r^2+L^2+\sqrt{3}\cdot r\cdot L})\cdot \Pr(\text{one GPS-MS in each circle})\\ &\quad + f(1)\cdot\{1-\Pr(\text{one GPS-MS in each circle})\} \qquad (1)\\ &= f(R+\sqrt{r^2+L^2+\sqrt{3}\cdot r\cdot L})\cdot P_V(L,R)\cdot P_U(L,R)\ + f(1)\cdot\{1-P_V(L,R)\cdot P_U(L,R)\} \end{aligned}$$

where

$$\text{"distance-r"}=R+\sqrt{r^2+L^2+\sqrt{3}\cdot r\cdot L}$$

for this MS

$$P_V(L,R)=1-(1-\pi R^2)^\rho,$$

$$P_U(L,R)=1-(1-\pi R^2)^\rho.$$

By unconditioning (1) on (r,θ), we obtain the average likelihood as

$$\eta=\int_0^{1/2}\int_0^{\pi/3}\frac{r}{(\pi/24)}\cdot g(r)\cdot d\theta dr=8\cdot\int_0^{1/2}g(r)dr$$

$$=8\cdot\left\{\int_0^{1/2}f(R+\sqrt{r^2+L^2+\sqrt{3}\cdot r\cdot L})dr\cdot\{1-(1-\pi R^2)^\rho\}^2+\frac{1}{8}f(1)\cdot\{1-\{1-(1-\pi R^2)^\rho\}^2\}\right\}$$

$$\begin{aligned}&=8\{1-(1-\pi R^2)^\rho\}^2\cdot\int_0^{1/2}f(R+\sqrt{r^2+L^2+\sqrt{3}\cdot r\cdot L})dr\\ &\quad + f(1)\cdot\{1-\{1-(1-\pi R^2)^\rho\}^2\}.\end{aligned}$$

Fig. 3 presents a lower bound of the likelihood and it demonstrates that the likelihood by the proposed mechanism is greater than 1 given that the likelihood function is given by $f(x) = x^{-1},\ 0 < x < 1$.

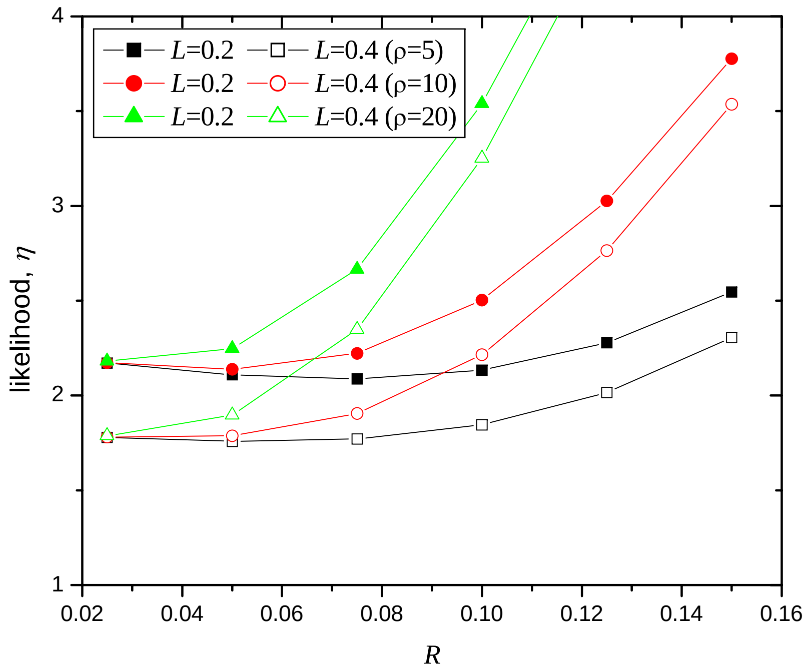


Fig. 3. A lower bound of “likelihood”.