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# Problem Statement

- One of the key requirements in public safety domain is to know the exact location of user or wearable device. Especially, Indoor position accuracy is very critical in public/children/women safety and emergency services.
- There are a plethora of IoT based wearable devices which are getting used for alerting with position coordinates, but detection of indoor positioning is less accurate when the object is in basement/deep indoor.
- Traditional location accuracy technologies such as GNSS or GPS are generally not suitable to establish indoor locations due to challenges of microwaves attenuation and scattering by roofs, walls and other objects.
- As Per United States Federal Communications Commission (FCC) the majority of wireless calls are now made indoors; and the majority of calls to 911 are from wireless phones.
- FCC adopted an order on January 29th, 2015 in which, all carrier providers must provide location coordinates (x/y) within 50 meters, for the 40% of wireless 911 calls within 2 years and for 80% of wireless 911 calls within 6 years.

*b) Explain the technical problem you are solving*

# Problem Statement

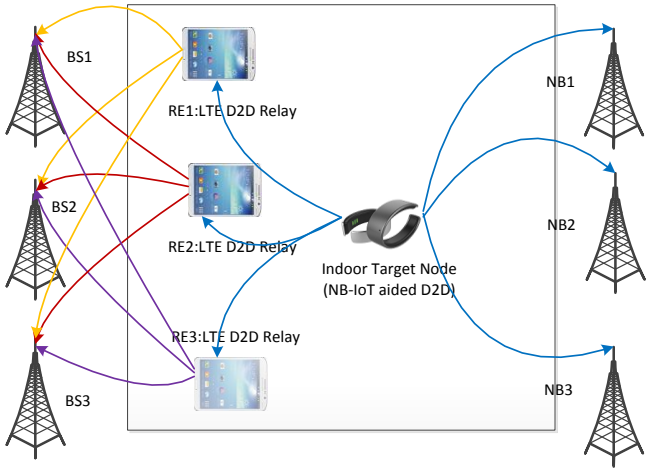
- To meet these new requirements enhancements are proposed for existing 3GPP positioning methods such as OTDOA, E-CID and D2D etc. Interworking with Non-3GPP positioning methods such as TBS, Wi-Fi/BT and barometer sensing methods are also considered.
  - OTDOA is a Location based service, in which UE measures the observed time difference of arrival from neighboring base stations to serving base station, which is used by network entity to calculate the position of UE. The measured time difference of arrival from serving to neighboring base stations is called Reference Signal Time Difference (RSTD) is reported to NW. NW based on the positions of base stations and received RSTD calculates the position of UE.
  - Device To Device(D2D) is a mechanism in which direct communication between mobiles is enabled without going through base station or core network.
- ***Based on the literature survey, we can say that the current state of art suffer the accuracy in the positioning, when object is in deep coverage area even with all these proposed enhancements***.

# Solution

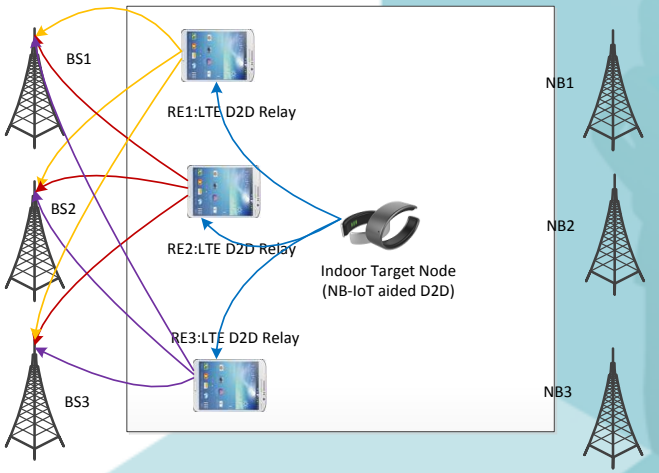
- In our solution we have considered NB-IoT along with already proposed D2D Relay mechanism for indoor positioning.
  - NB-IoT is a narrow band system that has been introduced to provide low-cost, low power, wide-area cellular connectivity for the Internet of Things. One of the NB-IoT objective is ***high coverage (20dB)*****, which will be helpful in improving the positioning accuracy of indoor objects.**
- Widely used methods for positioning accuracy are Kalman Filter and Particle Filter. For evolution purposes we have used Particle Filter in our study.

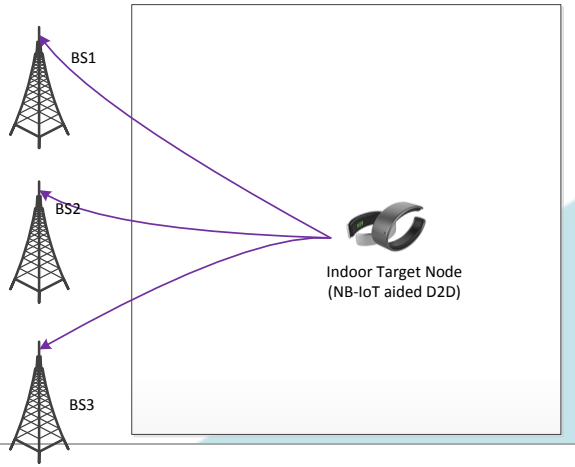
# Scenarios Considered for Evolution

Scenario 1:
Target in the coverage area of NB-IoT, but not in Macro cell




Scenario 2: Target not in the coverage area of Macro or NB-IoT




Scenario 3:
Target in the coverage area of Macro cell

# Reference Signals Used for Evolution

- OTDOA based method is considered to measure the position of relay nodes (using LTE macro and small cells) and hierarchically use it to measure the position of target node using these relay nodes and NB-IoT cell.
- Positioning Reference Signal is used to get the relay node positions by applying OTDOA algorithm in case of LTE macro cell
- NB-IoT reference signal and D2D discovery signals are considered to calculate RSTD measurements for OTDOA

# Indoor Positioning Algorithm

**Step 1**

**Input**: V=Bs, positions of elements of V, N = |V|, **Output**: Location of relay node

For each Relay Node

1. Compute delay from each element of V to relay node
2. Correlate the received reference signal from each element of V with locally generate reference signal.
3. Estimate arrival time of signal from each element of V at the relay node as position of the correlation peak.
4. Estimate time difference of arrival at relay node for each pair of elements of V as the intersection of circles generated with the elements in the pair as center. Generate hyperbolas of constant delay difference using various possible radii which intersects at the relay node location
5. Find the intersection point of hyperbolas using steepest descent.
6. After each measurement, update the intersection point using Taylor series expansion.

END

**Step 2**

**Input:** (scenario 1) V = Re U Nb or (scenario 2) V = Re, N = |V|, **Output:** Location of the indoor target node

Run Step 1 with updated input set and get indoor target node location.

# Simulation Environment

For simulation purpose, Relay nodes are considered as static. NB-IoT base stations and LTE base stations are static by default

| | |
|---|---|
| **No of LTE base station - Bs** | **3** |
| **No of NB-IoT base station - Nb** | 3 |
| **Relay Node (LTE D2D device) - Re** | 3 |
| **Target Node -Tn** | 1 |

# Simulation Results

Resulting error in position coordinates detection

| | Bs (Macro cells) | Nb (NB-IoT Cells) | Nb and Re (NB-IoT + D2D Relays | Re (Only D2D Relays) |
|---|---|---|---|---|
| XX(meter) | 1.1 | 4.3 | 2.2 | 2.35 |
| YY(meter) | 0.4482 | 1.75 | 1.01 | 1.21 |

# Conclusions

- Proposed Indoor positioning of the target node (NB-IoT and D2D capable) using NB-IoT and LTE-D2D relay nodes have shown promising results.
- Relay node positioning inaccuracies can be propagated to target node resulting errors in the position coordinates of the target node.
- This inaccuracy can be addressed by choosing best LTE-D2D relay nodes while calculating positioning for the target node.
- Our future work involves usage of unscented particle filters to mitigate the inaccuracy caused due to the LTE D2D relay mechanism and mobility aspects.

# References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