# 专题：物联网的定位机制以及基于位置的服务

谢磊 博士
南京大学计算机科学与技术系

# 主要内容：

一、定位技术背景(Location-aware technology)

二、定位机制研究（ Localization ）

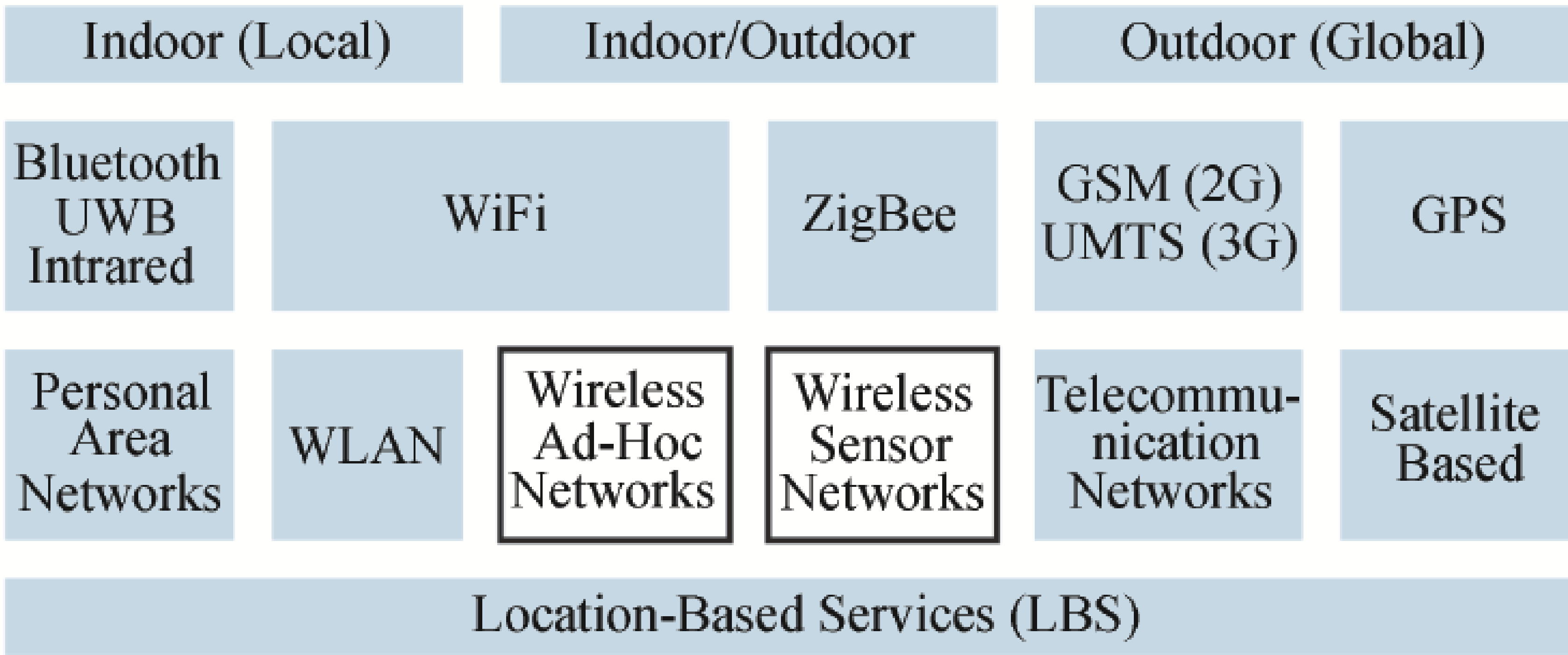
三、基于位置的服务(Location based Service):架构与进展

四、参考文献

# 定位技术背景(Location-aware technology)

- The proliferation of wireless and mobile devices has fostered the demand for context-aware applications, in which location is viewed as one of the most significant contexts.
  - pervasive medical care
  - smart space
  - goods transportation, inventory, and warehousing
- Location-based service (LBS) is a key enabling technology of these applications and widely exists in nowadays wireless communication networks from the short-range Bluetooth to the long-range telecommunication networks.

# 定位技术背景(Location-aware technology)




**Location-based services for a wide range of wireless networks.**

# 定位技术背景(Location-aware technology)

- Location information also supports many fundamental network services, including
  - network routing,
  - topology control,
  - coverage,
  - boundary detection,
  - clustering, etc.

# 定位机制研究（Localization）

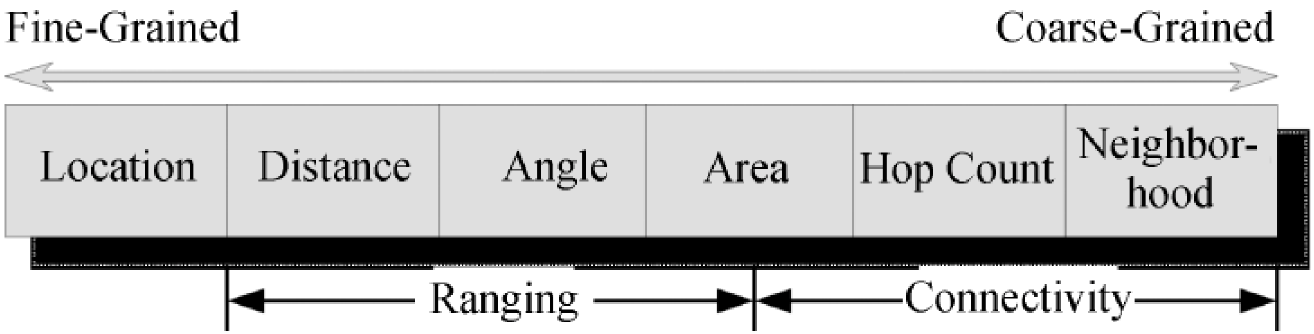
- Existing positioning systems
  - Manual configuration is often infeasible for large-scale deployments or mobile systems.
  - Global Positioning System (GPS) is not suitable for indoor or underground environments and suffers from high hardware cost.
  - Local Positioning Systems (LPS) rely on high density base stations being deployed, an expensive burden for most resource-constrained wireless ad hoc networks.
- The limitations of existing positioning systems motivate a novel scheme of network localization.
  - Some special nodes (a.k.a. anchors or beacons) know their global locations and the rest determine their locations by measuring the geographic information of their local neighboring nodes.

# 定位机制研究（Localization）

- Almost all existing localization algorithms consist of two stages:
  - 1) measuring geographic information from the ground truth of network deployment;
  - 2) computing node locations according to the measured data.
- Geographic information includes a variety of geometric relationships from coarse-grained neighbor-awareness to fine-grained inter-node rangings (e.g., distance or angle)
- Based on physical measurements, localization algorithms solve the problem that how the location information from beacon nodes spreads network-wide.
- Generally, the design of localization algorithms largely depends on a wide range of factors, including resource availability, accuracy requirements, and deployment restrictions.

# 定位机制研究（Localization）

- Physical Measurements and Single-Hop Positioning
  - According to the capabilities of diverse hardwares, we classify the measuring techniques into six categories (from fine-grained to coarse-grained): location, distance, angle, area, hop count, and neighborhood.




  - Distance and angle measurements are obtained by ranging techniques.
  - Hop count and neighborhood are basically based on radio connectivity.
  - In addition, area measurement relies on either ranging or connectivity, depending on how the area constrains are formed.

# 定位机制研究（Localization）

- Distance Measurements
  - The distances from an unknown node to several references constrain the presence of this node, which is the basic idea of the so called multilateration.
  - A to-be located node (node 0) measures the distances from itself to three references (nodes 1, 2, 3). Obviously, node 0 should locate at the intersection of three circles centered at each reference position. The result of trilateration is unique as long as three references are non-linear.

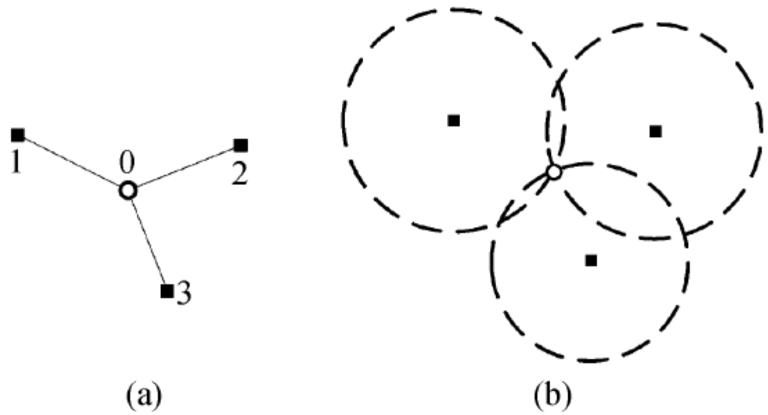



Fig.3. Trilateration. (a) Measuring distance to 3 reference nodes.
(b) Ranging circles.

# 定位机制研究（Localization）

- Suppose the location of the unknown node is ($x0$, $y0$) and it is able to obtain the distance estimates $d'_i$ to the $i$-th reference node locating at ($xi$, $yi$). Let $di$ be the actual Euclidean distance to the $i$-th reference node, i.e.,

$$d_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2}.$$

- The difference between the measured and the actual distances can be represented by $\rho_i = d'_i - d_i$. Owing to ranging noises in $d'_i$ , $\rho_i$ is often non-zero in practice.
- The least squares method is used to assign a value to ($x0$, $y0$) that minimizes $\sum_{i=1}^{n} \rho^2{}_i$. This problem can be solved by a numerical solution to an over-determined linear system.

# 定位机制研究（Localization）

- So far, for distance-based positioning, the only thing omitted is how to measure distances in the physical world. Many ranging techniques are proposed and developed; among them, *the radio signal strength based* and *time based ranging* are two of the most widely used ones in existing designs.
- (a) *Radio Signal Strength Based Distance Measurement*
  - Radio Signal Strength (RSS) based ranging techniques are based on the fact that the strength of radio signal diminishes during propagation.
  - In theory, radio signal strengths diminish with distance according to a power law. A generally employed model for wireless radio propagation is as follows:

# 定位机制研究（Localization）

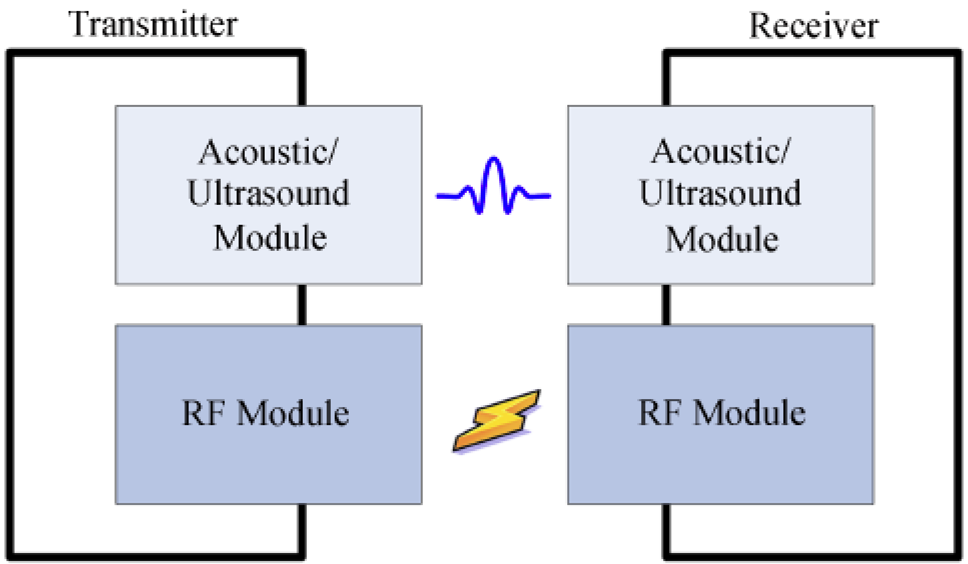
- (a) *Radio Signal Strength Based Distance Measurement*

$$P(d) = P(d_0) - \eta 10 \log\left(\frac{d}{d_0}\right) + X_\sigma$$

  - $P(d)$ is the received power at distance $d$, $P(d0)$ is the received power at some reference distance $d0$, $\eta$ the path-loss exponent, and $X_\sigma$ a log-normal random variable with variance $\sigma^2$ that accounts for fading effects.
  - Hence, if the path-loss exponent for a given environment is known, the received signal strength can be translated to the signal propagation distance.
  - In practice, RSS-based ranging measurements contain noises on the order of several meters. The ranging noise occurs because radio propagation tends to be highly dynamic in complicated environments.

# 定位机制研究（Localization）

- (b) *Time Difference of Arrival* (*TDoA*)
  - A more promising technique is the combined use of ultrasound/acoustic and radio signals to estimate distances by determining the Time Difference of Arrival (TDoA) of these signals.



# 定位机制研究（Localization）

- (b) *Time Difference of Arrival* (*TDoA*)
  - The idea of TDoA ranging is as follows: The transmitter first sends a radio signal. It waits for some fixed internal of time, $t_{delay}$ (which might be zero), and then produces a fixed pattern of "chirps" on its speaker.
  - When receivers hear the radio signal, they record the current time, $t_{radio}$, and then turn on their microphones. When their microphones detect the chirp pattern, they again record the current time, $t_{sound}$. Once they have $t_{radio}$, $t_{sound}$, and $t_{delay}$, the receivers can compute the distance *d* to the transmitter by

$$d = \frac{v_{\text{radio}} \cdot v_{\text{sound}}}{v_{\text{radio}} - v_{\text{sound}}} \cdot (t_{\text{sound}} - t_{\text{radio}} - t_{\text{delay}}),$$

where $v_{radio}$ and $v_{sound}$ denote the speeds of radio and sound waves respectively.

# 定位机制研究（Localization）

- (b) *Time Difference of Arrival* (*TDoA*)
  - The TDoA computation model is as follows:

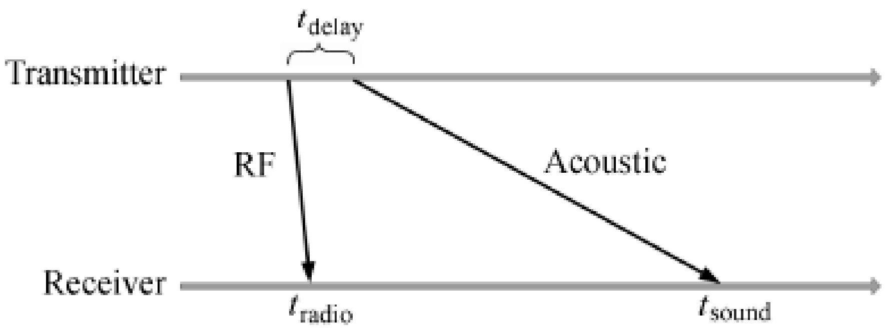



Fig.5. TDoA computation model.

  - TDoA methods are impressively accurate under line-of-sight conditions.

# 定位机制研究（Localization）

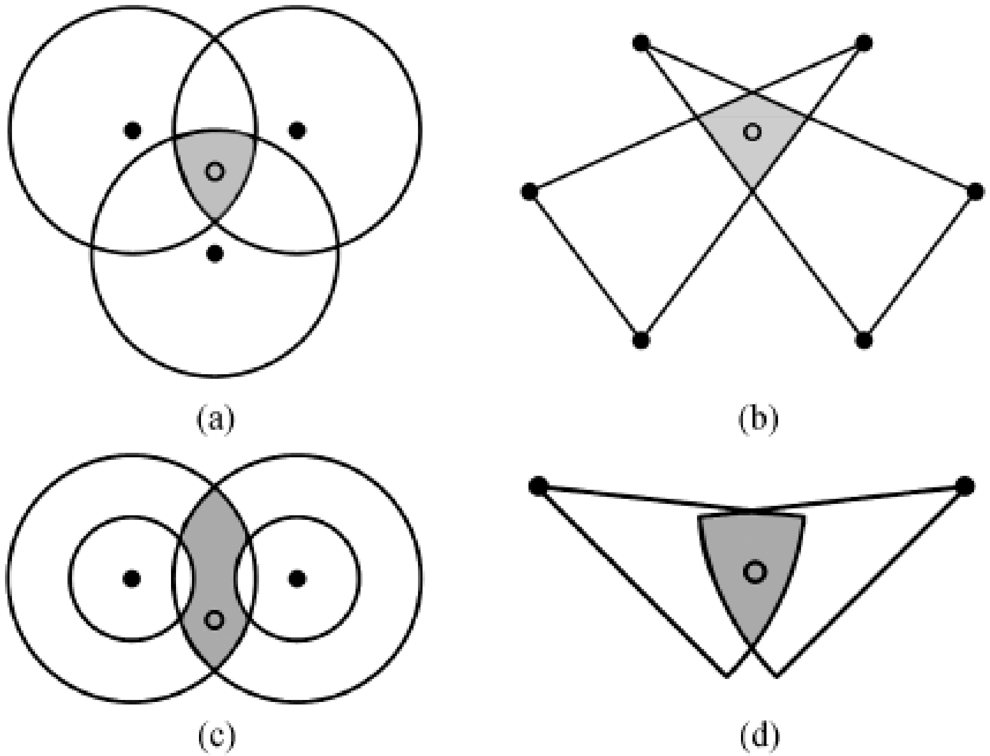
- Angle Measurement
  - Another approach for localization is the use of angular estimates instead of distance estimates. In trigonometry and geometry, triangulation is the process of determining the location of a point by measuring angles to it from two known reference points at either end of a fixed baseline, using the law of sines.
  - Triangulation was once used to find the coordinates and sometimes the distance from a ship to the shore.
  - The Angle of Arrival (AoA) data is typically gathered using radio or microphone arrays, which allow a receiver to determine the direction of a transmitter. Suppose several (3-4) spatially separated microphones hear a single transmitted signal. By analyzing the phase or time difference between the signal arrivals at different microphones, it is possible to discover the AoA of the signal.

# 定位机制研究（Localization）

- Area Measurement
  - If the radio or other signal coverage region can be described by a geometric shape, locations can be estimated by determining which geometric areas that a node is in.
  - The basic idea of area estimation is to compute the intersection of all overlapping coverage regions and choose the centroid as the location estimate. Along with the increasing number of constraining areas, higher localization accuracy can be achieved.
  - According to how area is estimated, we classify the existing approaches into two categories: *single reference area estimation* and *multi-reference area estimation*.

# 定位机制研究（Localization）

- Area Measurement



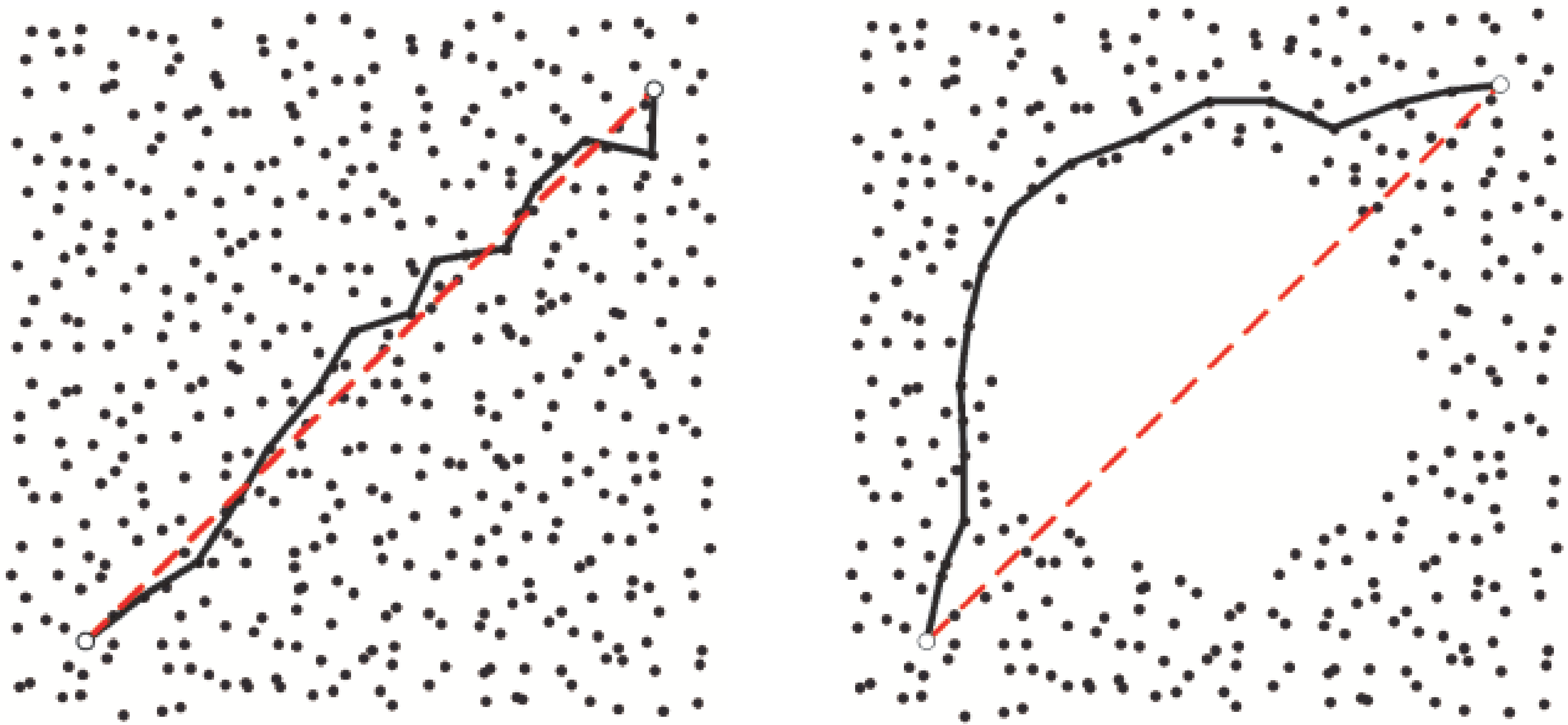
(a) (b) (c) (d)

# 定位机制研究（Localization）

- Hop Count Measurements
  - Based on the observation that if two nodes can communicate by radio, their distance from each other is less than *R* (the maximum range of their radios) with high probability, many delicate approaches are designed for accurate localization. In particular, researchers have found “hop count” to be a useful way to compute inter-node distances.
  - The local connectivity information provided by the radio defines an unweighted graph, where the vertices are wireless nodes and edges represent direct radio links between nodes.
  - The hop count *hij* between nodes *si* and *sj* is then defined as the length of the shortest path from *si* to *sj* . Obviously, the physical distance between *si* and *sj* , namely, *dij* , is less than *R*hij* , the value which can be used as an estimate of *dij* if nodes are densely deployed.

# 定位机制研究（Localization）

- Hop Count Measurements



(a) (b)

# 定位机制研究（Localization）

- Neighborhood Measurement
  - The radio connectivity measurement can be considered economic since no extra hardware is needed. Perhaps the most basic positioning technique is that of one neighbor proximity, involving a simple decision of whether two nodes are within the reception range of each other.
  - A set of reference nodes is placed in the network with some non-overlapping sub-regions. Reference nodes periodically emit beacons including their location IDs. Unknown nodes use the received locations as their own location, achieving a course-grained localization. The major advantage of such a neighbor proximity approach is the simplicity of computation.

# 定位机制研究（Localization）

- Neighborhood Measurement
  – The neighborhood information can be more useful when the density of reference nodes is sufficiently high so that there are often multiple reference nodes within the range of an unknown node.
  – Let there be k reference nodes within the proximity of the unknown node. We use the centroid of the polygon constructed by the k reference nodes as the estimated position of the unknown node.

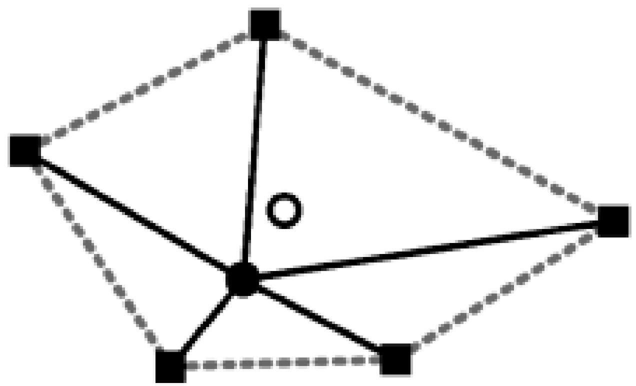


Fig.8. $k$-neighbor proximity.

# 定位机制研究（Localization）

- Comparative Study of Physical Measurements

**Table 1.** Comparative Study of Physical Measurements

| Physical Measurements | | Accuracy | Hardware Cost | Computation Cost |
|---|---|---|---|---|
| Distance | RSS | Median | Low | Low |
| | TDoA | High | High | Low |
| Angle | AoA | High | High | Low |
| Area | Single reference | Median* | Median* | Median |
| | Multi-reference | Median* | Median* | High |
| Hop Count | Per-hop distance | Median | Low | Median |
| Neighborhood | Single neighbor | Low | Low | Low |
| | Multi-neighbor | Low | Low | Low |

*: depends on the diverse geometric constrains

# 定位机制研究（Localization）

- Network-Wide Localization
- Centralized algorithms
  - *Centralized algorithms* are designed to run on a central machine with powerful computational capabilities. Network nodes collect environmental data and send back to a base station for analysis, after which the computed positions are delivered back into the network.
  - *Centralized algorithms* resolve the computational limitations of nodes. This benefit, however, comes from accepting the communication cost of transmitting data back to a base station. Unfortunately, communication generally consumes more energy than computation in existing network hardware platforms.

# 定位机制研究（Localization）

- Centralized localization
- (a) *Multi-Dimensional Scaling* (*MDS*)
  - The intuition behind MDS is straightforward. Suppose there are n points, suspended in a volume. We do not know the positions of the points, but we know the distances between each pair of points.
  - MDS is an $O(n^3)$ algorithm that uses the law of cosines and linear algebra to reconstruct the relative positions of the points based on the pairwise distances.

# 定位机制研究（Localization）

- Centralized localization
- *(b) SemiDefinite Programming (SDP)*
  - In SDP, geometric constraints between nodes are represented as linear matrix inequalities (LMIs). Once all the constraints in the network are expressed in this form, the LMIs can be combined to form a single semi-definite program, which is solved to produce a bounding region for each node.
  - The advantage of SDP is its elegance on concise problem formulation, clear model representation, and elegant mathematic solution.
  - Solving the linear or semi-definite program has to be done centrally.

# 定位机制研究（Localization）

- Network-Wide Localization
- Distributed algorithms
  - Distributed algorithms are designed to run in network, using massive parallelism and inter-node communication to compensate for the lack of centralized computing power, while at the same time to reduce the expensive node-to-sink communications.
  - Distributed algorithms often use a subset of the data to locate each node independently, yielding an approximation of a corresponding centralized algorithm where all the data are considered and used to compute the positions of all nodes simultaneously.

# 定位机制研究（Localization）

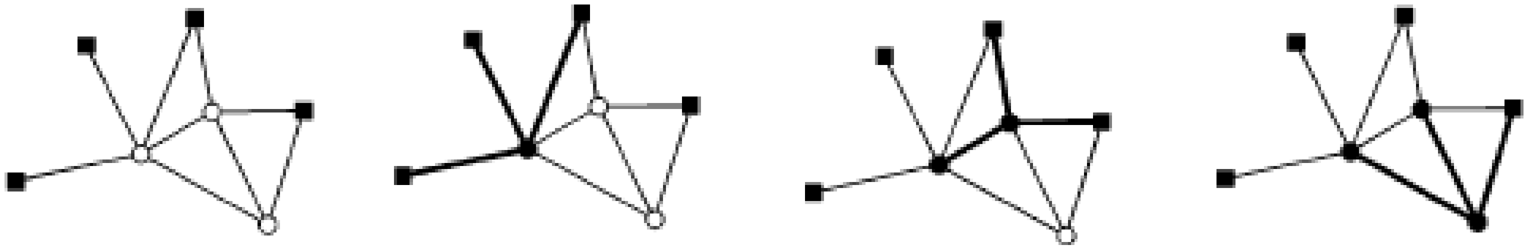
- Distributed algorithms
- *(a)Beacon Based Localization (Top-down approach)*
  - Beacon based localization approaches utilize estimates of distances to reference nodes that may be several hops away. These distances are propagated from reference nodes to unknown nodes using a basic distance-vector technique. Such a mechanism can be seen as a top-down manner due to the progressive propagation of location information from beacons to an entire network. There are three types as follows.
  - 1) DV-hop: Each unknown node determines its distance from various reference nodes by multiplying the least number of hops to the reference nodes with an estimated average distance per hop that depends upon the network density.

# 定位机制研究（Localization）

- *(a)Beacon Based Localization (Top-down approach)*
  - 2) DV distance: If inter-node distance estimates are directly available for each link in the graph, the distance-vector algorithm is used to determine the distance corresponding to the shortest distance path between the unknown nodes and reference nodes.
  - 3) Iterative localization: One variant of above approaches is indirect use of beacon nodes. Initially an unknown node is located based on its neighbors by multilateration or other positioning techniques. After being aware of its location, it becomes a reference node to localize other unknown nodes in the subsequent localization process. This step continues iteratively, gradually turning the unknown nodes to the known.

# 定位机制研究（Localization）

- *(a)Beacon Based Localization (Top-down approach)*
  - The process of iterative localization is illustrated as follows:

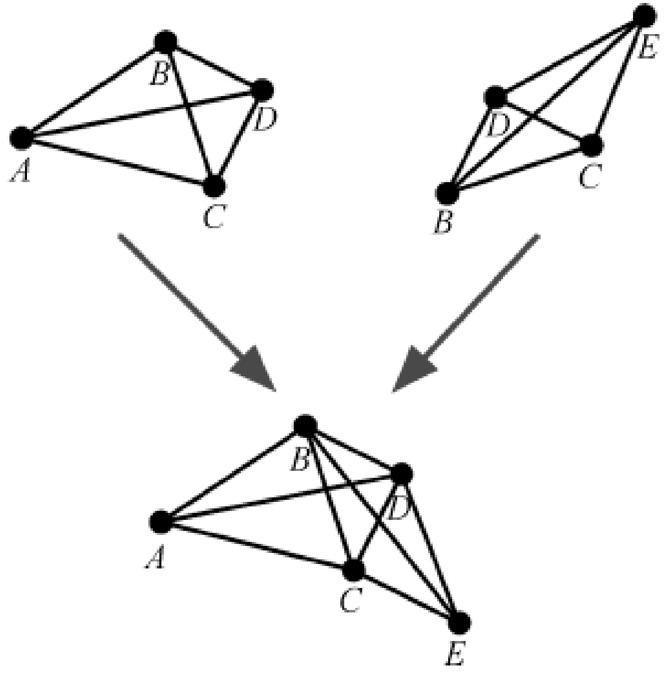


(a) (b) (c) (d)

  - Iterative trilateration only involves local information (information within neighborhood) and accordingly reduces communication cost. Nevertheless, the use of localized unknown nodes as reference nodes inherently introduces substantial cumulative error.

# 定位机制研究（Localization）

- Distributed algorithms
- *(b) Coordinate System Stitching*
  - It works in a bottom-up manner, in which localization is originated in a local group of nodes in relative coordinates. By gradually merging such local maps, it finally achieves entire network localization in global coordinates, as illustrated in the following figure.



# 定位机制研究（Localization）

- Comparative Study of Localization Algorithms
- (a) *Beacon Nodes*
  - Higher localization accuracy can be achieved if beacons are placed in a convex hull around the network.
  - Placing additional beacons in the center of the network is also helpful.
  - Thus, it is necessary for system designers to plan the beacon layout before deploying a network.
- (b) *Node Density*
  - Algorithms that depend on beacon nodes fail when the beacon density is not sufficiently high in a specific region.
  - Thus when designing or analyzing an algorithm, it is important to consider its requirement on node density, since high density may not be always true.

# 定位机制研究（Localization）

- Comparative Study of Localization Algorithms
- (c) *Accuracy*
  - Location *accuracy* is defined as the expected Euclidean distance between the location estimate and the actual location of an unknown node, while location *precision* indicates the percentage of the results satisfying a pre-defined accuracy requirement.
  - For a given localization result, location accuracy trades off with location precision. If we relax the accuracy requirement, we can increase precision, and vice versa.
  - The error propagation demonstrates how location accuracy varies with the increase of measurement error. Intuitively, localization error is linear with measurement error. However, it is not true for many localization systems.

# 定位机制研究（Localization）

- Comparative Study of Localization Algorithms
- (d) *Cost*
  - In general, the cost of a localization system includes hardware cost and energy cost.
  - Hardware cost consists of three parts: node density, beacon density, and measurement equipment.
  - A localization procedure often involves inter-node measurement, computation and communication, among which communication consumes most energy. This is why distributed algorithms are often more compelling than centralized algorithms.

# 定位机制研究（Localization）

- Comparative Study of Localization Algorithms

Table 2. Comparative Study of Localization Algorithms

| Localization Algorithm | | Accuracy | Node Density | Beacon Percentage | Computation Cost | Communication Cost | Error Propagation |
|---|---|---|---|---|---|---|---|
| Centralized | MDS | High | Low | Low | High | High | Low |
| | SDP | High | High | Median | High | High | Low |
| Distributed | Beacon based | Low | High | High | Low | Low | High* |
| | Coordinate stitching | Low | High | Low | Median | Median | High |

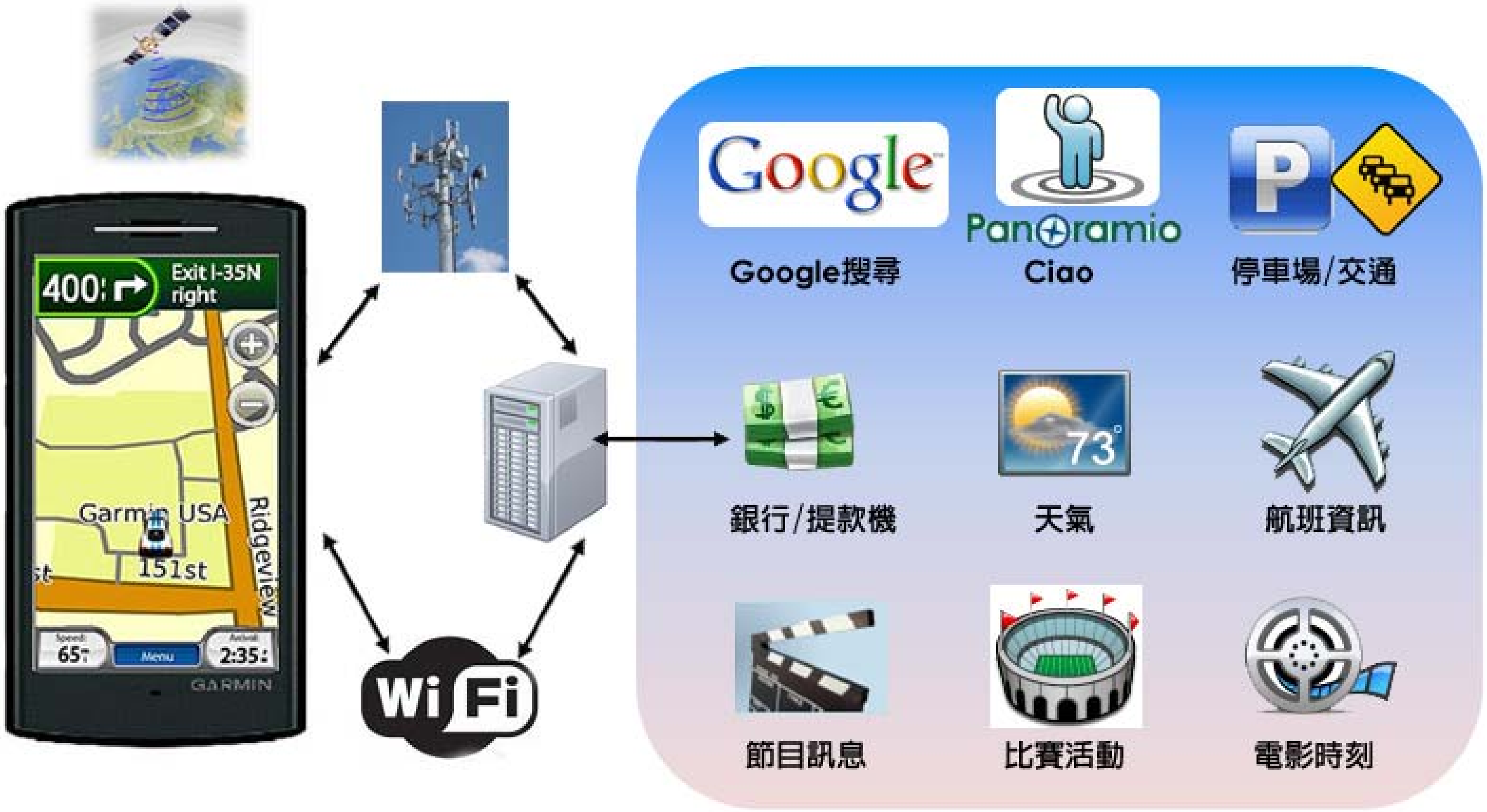
∗: in case of iterative localization

- All approaches have their own merits and drawbacks, making them suitable for different applications.
- Hence, the design of a localization algorithm should sufficiently investigate application properties, as well as take into account algorithm generality and flexibility.
- In future study, obtaining a Pareto improvement is a major challenge. That is, increasing the performance of one of the metrics without degradation on others.

# 基于位置的服务(Location based Service)

- 基于位置的服务（LBS）
  - LBS是指移动终端利用各种定位技术获得当前位置信息，再通过无线网络得到某项服务。
  - 例如，司机可以利用内置GPS功能的智能手机查找最近的加油站，也可制定行车线路。在大型博物馆内，游客可以借助一个能感知位置的语音导游器来欣赏对各个藏品讲解。
  - LBS区别于其它传统网络服务的一大特点就是上下文感知性(Context-ware)以及应对上下文变化的适应性(adaptation)。上下文是指描述某个实体状态的任何信息。具体包括：移动地图用户、位置、时间、运动方向、导航历史、使用目的、社会和文化状况、物理环境和系统属性。

# 基于位置的服务(Location based Service)



# 基于位置的服务(Location based Service)

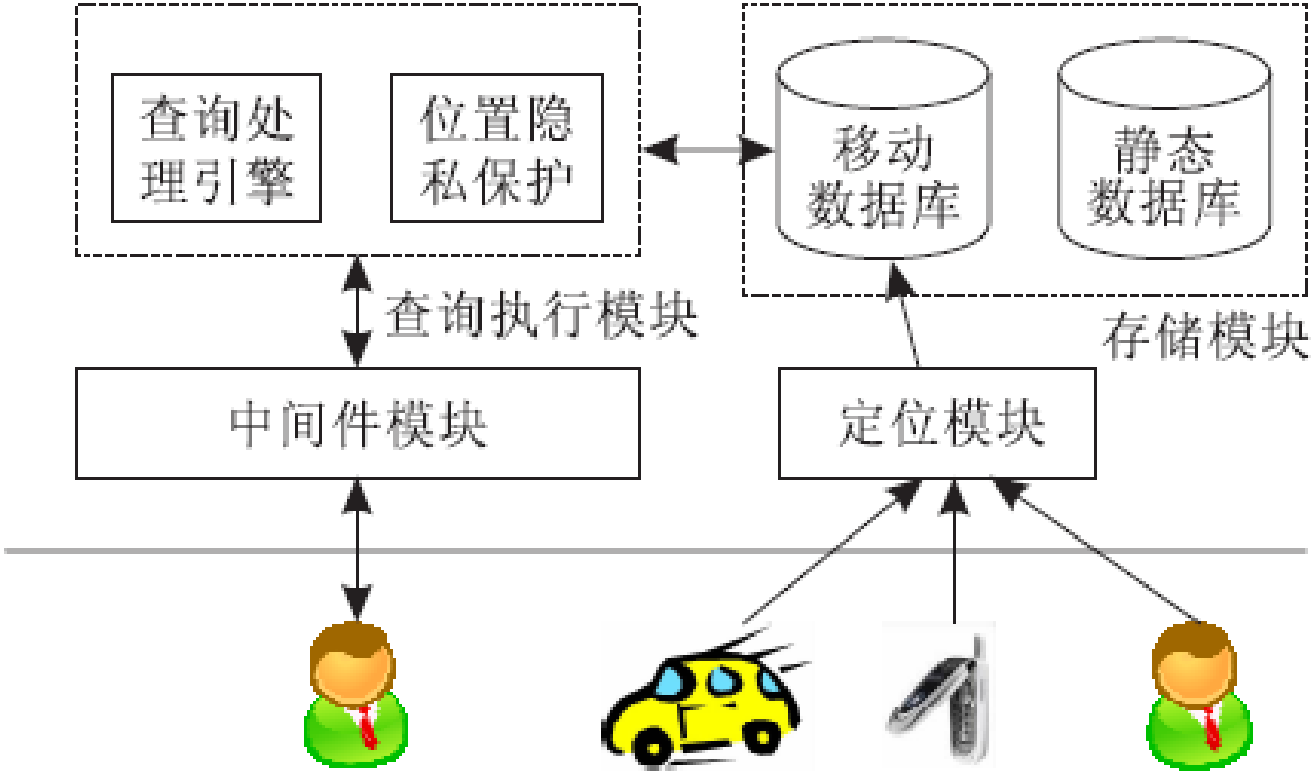



图 1 LBS 系统的架构

# 基于位置的服务(Location based Service)

- LBS系统架构
  - 通过定位技术实时获取用户/移动对象的位置信息，并发送到LBS系统中去。LBS系统将这些位置信息保存在移动对象数据库(Moving Object Database)之中，通过构建特定的索引来提高访问效率。LBS系统还需要保留一些静态GIS信息。
  - 用户向LBS系统发出服务请求，并获取服务。LBS中间件是用户与LBS系统之间的通信媒介，它具有多种模型，包括基于内容的模型、基于主题空间的模型和元组空间模型等，前两个模型又被称为发布/订阅模型(publish /subscribe model)。

# 基于位置的服务(Location based Service)

- LBS系统架构
  - LBS系统的查询处理引擎访问移动对象数据库和静态数据库，从而提供用户所需的服务。
  - 为了保护用户的隐私，LBS系统一般还有位置隐私保护模块，从而不会在向用户提供服务的过程中泄露用户的隐私。位置隐私保护模块有时也涉及到与第三方可信机构之间的交互。

# 基于位置的服务(Location based Service)

- LBS的分类：拉动服务和推送服务
  - 根据服务信息的投递是否需要用户的直接交互，LBS可以分为拉动服务(pull services)和推送服务(push services)。
  - 拉动服务是指由用户主动发送明确的服务请求，服务提供商把所需信息返回给用户，就如同用户把所需要的信息从服务提供商那里“拉”到用户自己这里。
  - 推送服务则和拉动服务相反，用户没有明确发送服务请求，而是当某一条件满足时，服务提供商自动将相关信息返回给用户。推送服务可以分为用户事先同意和用户事先未同意两个子类。

# 基于位置的服务(Location based Service)

- LBS的分类：拉动服务和推送服务
  - 用户事先同意的服务通常是通过向服务提供商订阅实现，比如：用户订阅根据当前位置提供天气预报信息的服务．当用户从上海到达北京时，服务提供商就将北京的天气资料发给该用户。
  - 用户未事先同意的服务一般指的是广告投递服务，比如：服务提供商将某商场的促销信息发送给周边的用户。

# 基于位置的服务(Location based Service)

- LBS的分类：快照查询服务和连续查询服务
  - 根据服务处理技术的不同，LBS又可以分为快照查询服务(snapshot queries)和连续查询服务(continuous queries)。
  - 快照查询服务根据查询条件，一次执行，返回结果；
  - 连续查询根据移动对象的位置变换信息持续更新查询结果。通常情况下，推送服务通过连续查询来实现。

# 基于位置的服务(Location based Service)

- LBS索引技术
  - 索引技术是移动对象数据库的核心技术，决定了LBS的查询性能。
  - 对空间数据的索引技术的研究工作已经开展了２０余年的时间，出现了RTree家族、KDTree家族和QuadTree家族等代表性的索引技术。这类空间索引技术能够有效实现对静态空间对象的索引。然而，当移动对象频繁移动时，上述索引技术的性能显著下降。
  - 近年来出现了一批有针对性的移动对象历史轨迹索引技术和移动对象当前/将来位置索引技术。历史轨迹索引技术不仅考虑对象的空间位置，也考虑时间维度；当前/将来位置索引技术则对于移动对象位置的更新操作具有良好的适应。

# 基于位置的服务(Location based Service)

- LBS中间件模型
  - 中间件技术广泛地用于移动计算环境之中。LBS系统将中间件作为服务处理引擎与终端用户之间的软件载体，隐藏了具体技术细节，便于向客户端提供服务。
  - 主要的LBS中间件模型有三种，包括:
    - 基于内容的模型（content based model）
    - 基于主题空间的模型（subject space based model）
    - 基于元组空间模型（tuple space model）
  - 前两个模型又可被归为发布／订阅模型（publish/subscribe model）。

# 基于位置的服务(Location based Service)

- LBS中间件模型
  - 发布/订阅模型是移动计算中应用最为广泛的中间件模型之一。该模型中有两个角色：发布者和订阅者（也称消费者），二者之间通过事件交换信息。发布者产生事件，订阅者向发布者发送订阅请求。
  - 当特定事件发生时，即可将该事件通知订阅者。发布者与订阅者之间的联系并不紧密，是松耦合的；换言之，当订阅者暂时无法工作时，发布者仍可发布事件。

# 基于位置的服务(Location based Service)

- 基于内容的模型
  - 在本模型中，一个事件被描述为一组（属性，值）对，而订阅请求则被描述为一个事件相关的谓词。
  - 对于任一事件，检查所有订阅请求的谓词；当谓词为真时，则将该事件发布给订阅者。
  - 例如，假设某个LBS系统中某个移动对象产生的事件为{(id，”救护车”)，(location，(100，200))}，表明某一辆救护车的当前坐标是(100,200)。
  - 订阅者的请求是:(location，(x>100) and (x<120) and (y>150) and (y<180))，表示订阅者对于空间矩形框(左下角坐标(100,150)，右上角坐标(120,180))内的移动对象感兴趣。因此，这个事件不会发送到订阅者。

# 基于位置的服务(Location based Service)

- 服务处理方法：快照查询和连续查询
  - 从查询处理的技术角度，基于位置的服务通常包含两类查询服务：快照查询和连续查询。
  - 快照查询访问移动对象数据库后立即返回查询结果。典型的快照查询如：“查询当前离我最近的快餐店”。
  - 连续查询根据周围环境变化情况持续刷新查询结果。例如，“监控未来一小时内某路口车流量变化”就是一个典型的连续查询。

# 基于位置的服务(Location based Service)

- 快照查询
  - 快照查询的处理较为简单。根据查询对象的时效性不同，快照查询大致可分为历史查询、当前查询和未来查询三类。
    - 历史查询用于查询过去时间内发生的事件，例如“查找哪些车辆昨天出现在停车场”；
    - 当前查询用于查询正在发生的事情，例如“查找哪些车辆现在出现在停车场”；
    - 将来查询则查询将要发生的事件，例如“查找哪些车辆将在五分钟后出现在停车场”。

# 基于位置的服务(Location based Service)

- 快照查询
  - 为了提高快照查询的执行效率，需要创建各种索引结构。
    - 对于历史查询，需要在时间/空间维度上对移动对象的历史运动轨迹进行索引。
    - 对于当前查询和未来查询，则需要对移动对象的当前位置进行索引，并维护移动对象的移动模型。这一类索引结构需要支持较多的更新操作。

# 基于位置的服务(Location based Service)

- 连续查询
  - 相比而言，连续查询的处理更为复杂，常用的策略有周期性快照查询法、增量处理法和查询感知处理法。
    - 周期性快照查询法：该方法是最朴素的连续查询处理方法，定期执行快照查询（通常是当前快照查询），并刷新查询结果。缺点是难以有效地定义周期值：过小的周期值将增加系统负荷，而过大的周期值会降低查询结果精度。
    - 增量处理法：根据初始结果，动态增加新数据或者删除过期数据。SINA定义了两类更新：正更新和负更新（从当前结果集内增加或删除一个移动对象），从而增量地更新查询结果。SINA通过散列、验证和连接３个步骤完成对连续查询的正负更新，从而有效地执行连续查询。Q index是另一种处理连续查询的索引结构。和通常的索引构建策略相反， Q index为所有查询建立索引，当移动对象的位置变化时，通过Q index可以找到受影响的查询，并更新相应的查询结果。

# 基于位置的服务(Location based Service)

- 连续查询
  - 查询感知处理法：该方法根据连续查询的查询条件计算出“安全区域”，只有当移动对象离开或进入“安全区域”时，才会影响查询结果。因此，系统可以忽略很多不影响查询结果的位置更新操作，进而降低系统负荷。
  - 如右图所示，给定5个范围查询，对象A的安全区域表示为一个以A为圆心的圆，而对象B的安全区域则是一个矩形。

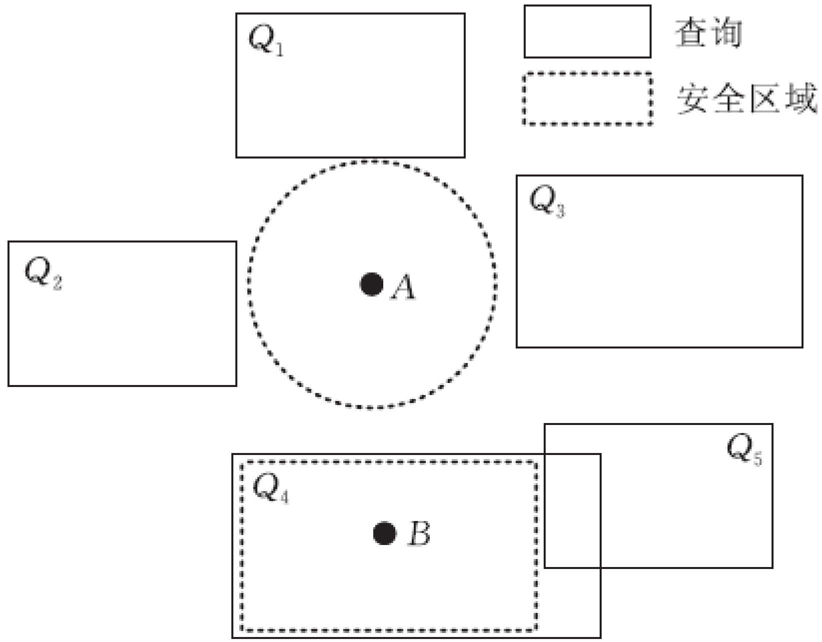



图 5　安全区域[32]

# 基于位置的服务(Location based Service)

- 分布式查询处理方法
  - 按照移动终端是否参与查询处理，服务处理方法可以分为集中式和分布式两种处理方式。
    - 在集中式方式中，仅服务提供商处理连续查询，移动终端并不参与查询处理。
    - 分布式方式中，服务提供商与移动终端协作完成连续查询处理。
  - Gedik等人提出了一种分布式连续查询处理架构MobiEyes，其核心思想是由移动终端来计算和判断是否是一个连续查询的结果，而中心服务器负责注册和维护连续查询的相关参数，并将参数传到相关移动终端。移动终端维护一个注册表以记录临近的一组连续查询，并周期性地检查自己是否属于这些查询的结果之中。若是，则向服务器报告。

# 基于位置的服务(Location based Service)

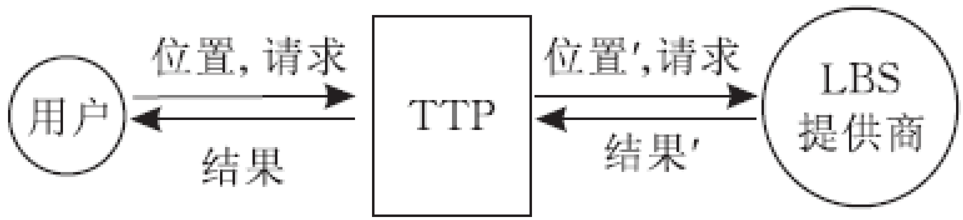
- 分布式查询处理方法
  - Cai等人则考虑到每个移动终端的计算和存储能力有差别，针对每个移动终端最多能处理的查询个数确定一存在区域，仅当移动对象离开存在区域时，才向中心服务器发送位置更新，并获取新的存在区域。移动终端在存在区域移动时，需要自己计算并检查是否是与该存在区域相关的连续查询的结果。
  - 与集中式方式相比，分布式方式通常需要在服务器与移动终端之间传递更多的消息，这带来两个问题：一是大量移动终端可能造成网络拥塞；二是网络通信会消耗移动终端的能量，缩短充电周期。另外，该方法无法适用于无计算能力的移动终端，如仅携带RFID标签的移动对象。

# 基于位置的服务(Location based Service)

- 隐私保护
  - 隐私保护是LBS的重要内容。用户并不期望由于接受了服务而向外界泄露了位置信息，这既包括当前的具体位置，也包括对象的移动习惯等。
  - 最常用的位置隐私解决方案是空间伪装（spatial cloaking），即用户将位置伪装成为一个区域之后再发送给服务提供商，服务提供商则根据用户所提供的区域信息为用户提供服务。在这种方式下，服务提供商无法准确得知用户的位置。
  - 事实上，用户隐私和服务质量是一对矛盾关系，需根据具体情况进行权衡。

# 基于位置的服务(Location based Service)

- 两大类隐私保护技术
  - **依赖于可信赖的第三方机构的技术：** 用户将位置信息发送给TTP(Trusted Third Party)，由TTP对位置信息做变换，之后再连同服务请求一起发送给服务提供商；服务提供商基于不精确的位置信息进行处理，并将服务结果返回给TTP。TTP经过过滤、取精后返回给用户。在此过程中，TTP的主要任务是将原始的、准确的位置信息转化为不准确的位置信息，以保护用户的隐私。



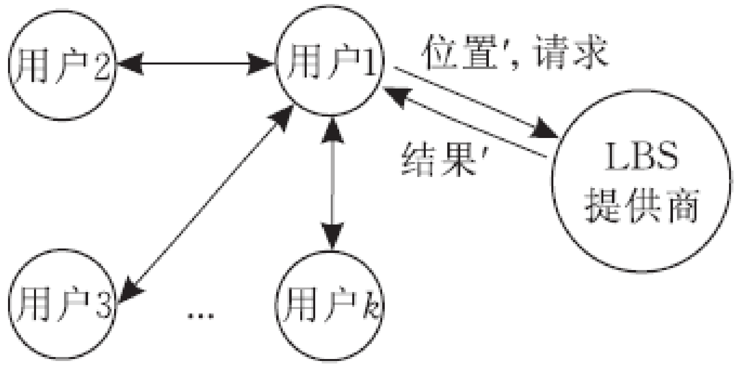

基于TTP的隐私保护方法

# 基于位置的服务(Location based Service)

- 两大类隐私保护技术
  - **依赖于可信赖的第三方机构的技术**:一种简单的方法是TTP直接用虚假标识符表示真实的用户标识符，再发送给服务提供商。但是，服务提供商仍可借助其它辅助信息进行破解，比如通过电话号码或家庭住址来推测真实用户信息。
  - K-匿名方法是另外一种使用较广泛的方法，其核心思想是以一个覆盖移动对象的矩形来描述该对象的真实位置，该矩形同时还包含另外k-1个对象，使得服务提供商无法将该对象与其余k-1个对象区分开来。

# 基于位置的服务(Location based Service)

- 两大类隐私保护技术
  - **不依赖于可信赖的第三方机构的技术:**有一些隐私保护技术并不依赖于TTP，其基本思想是用户和其它用户之间交互位置信息，进而构造伪装的位置，如图所示.




基于合作策略的非TTP隐私保护方法

  - 主要步骤如下：（１）请求服务的用户A首先将自身位置模糊化，并向周围的邻居广播；（２）邻居对象将模糊化之后的位置信息发送给用户A，直到A至少搜集到k-1个移动用户的位置信息；（３）用户A随机选取k-１个对象，与自身构成一个含k个对象的集合，并将包含这些对象的ＭＢＲ或任意一个非用户A对象的位置发送给服务提供商；（４）服务提供商根据接收到的位置提供服务。

# 基于位置的服务(Location based Service)

- 近期研究进展
  - 不确定的位置服务: 位置信息的不确定性源于多种因素。
    - 首先，非连续的定位采样会带来不确定性。一般来说，定位技术会定期汇报位置信息，因而移动对象的位置在相邻两次采样之间存在不确定性。其次，定位技术自身具有精度限制。
    - 再次，当以物体的历史运动轨迹和附加信息来预测其未来行为时也存在不确定性。
    - 最后，出于隐私保护目的，需将数据模糊化，人为地引入不确定性。
  - 不确定位置信息管理技术大致可分为如下几种情况:
    - 查询发出点精确，被查询的数据点是不确定的移动对象。
    - 查询发出点是不确定的移动对象，被查询的数据点是精确的。
    - 查询发出点和被查询数据点都是不确定的。
    - 不确定的移动速度。

# 基于位置的服务(Location based Service)

- 近期研究进展
  - 室内LBS技术
    - 室内空间模型
    - 室内轨迹索引
    - 连续查询处理
  - 非合作策略的不基于TTP的隐私保护方法
  - 社会化LBS
  - 针对紧急情况的LBS

# 基于位置的服务(Location based Service)

- 参考文献

[1] Liu Y, Yang Z, Wang X *et al*. Location, localization, and localizability. JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY 25(2): 274-297 Mar. 2010

[2]周傲英，杨彬，金澈清，马强。基于位置的服务：架构与进展. 计算机学报，2011，34（7）：1155～1171.

[3] Hui Liu, Darabi H., Banerjee P., Jing Liu. Survey of Wireless Indoor Positioning Techniques and Systems. IEEE Transactions on Systems, Man, and Cybernetics, 2007,37(6):1067 – 1080.

# 基于位置的服务(Location based Service)

- **课程作业2**（读书报告）

可选择如下之一的课题对相关论文进行阅读，并完成读书报告。要求对论文中的算法、协议以及相关内容进行总结、归纳。鼓励提出创新的研究思路和解决方案。

- **基于RFID技术的定位机制研究**
- **无线传感网中定位机制研究**
- **基于WiFI技术的定位机制研究**
- **基于位置服务（Location-based Service）的研究**