



基于位置服务中的隐私保护

孟小峰

中国人民大学信息学院

2009-12-18



报告大纲

- 隐私保护问题及意义
- 隐私保护系统结构
- 隐私保护研究内容
- 隐私保护面临挑战
- 总结



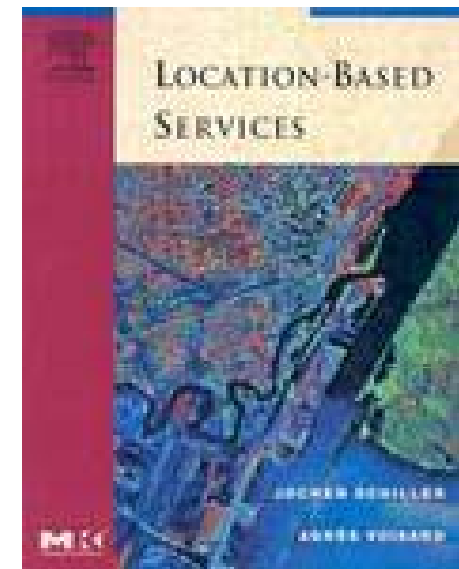
基于位置服务 (LBS)





基于位置服务

- Services that integrate a mobile device's location or position with other information so as to provide added value to a user
(基于位置的信息服务是将一个移动设备的位置或者坐标和其他信息整合起来，为用户提供增值服务)



J. Schiller, Jochen, A. Voisard, Location-based Services, Elsevier Science Ltd, April 2004

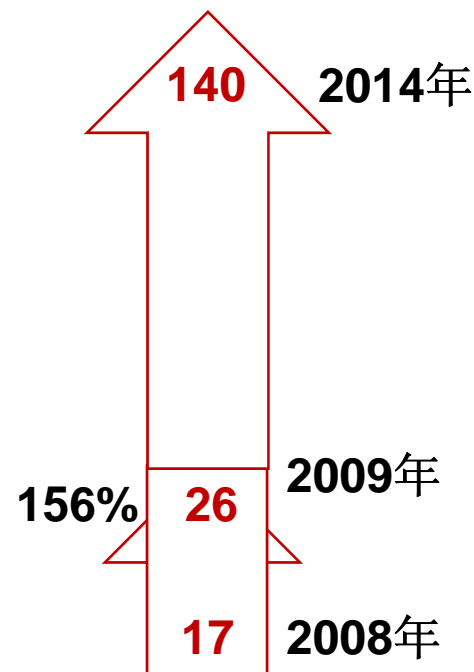
YOCSEF Forum (2009.12)



基于位置服务

□ 美国著名市场研究公司ABI research日前发布预测

LBS全球总收入
单位：亿美元



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Fixed Mobile Enterprise Consumer Infrastructure Devices Semiconductors Object Networks Digital Home

Global LBS Revenues to Reach \$2.6 Billion in 2009

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Contact: Christine Gallen
[Contact PR](#)
www.abiresearch.com

LONDON - September 3, 2009

ABI Research expects Location Based Services revenues to grow at 156% from \$1.7 billion in 2008 to \$2.6 billion in 2009. By 2014 global LBS revenues will have surpassed \$14 billion.

"One of the main drivers of the strong growth in LBS is the popularity of an impressive number of off-deck LBS applications available for a one-off fee on smartphone platforms," says ABI Research practice director Dominique Bonte. "Apple's iPhone is leading the way, followed by Blackberry, Nokia, and Android. There seems to be no limit to developers' creativity in using location for functions such as search, social networking, messaging, micro-blogging and augmented reality. Combined with the astonishing popularity of the new generation of GPS-enabled touch screen smartphones, this will continue to constitute the lifeblood of LBS in the coming years."

A More Open Strategy

Many carriers in both the US and Europe are waking up to this reality by gradually adopting a more open LBS strategy with Verizon increasing the number of unlocked GPS phones and Vodafone having acquired navigation software vendor Wayfinder. Both carriers are also making their networks accessible via open API platforms. Other carriers such as Sprint have opted to partner with location aggregators as a way to play a role in the LBS ecosystem.



LBS应用领域

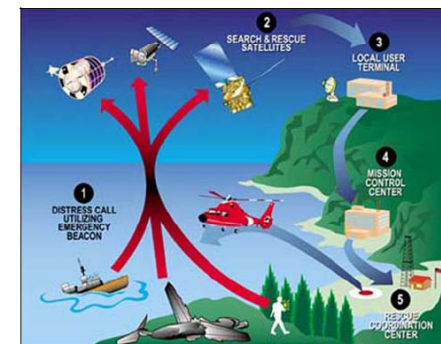
□ 军事和政府产业

- 全球第一个位置系统GPS，最初主要用于军事和涉及国家重要利益的民用领域



□ 紧急救援服务

- 1996年，联邦通信委员会（FCC）颁布E-911法规要求移动运营商为手机用户提供紧急救援服务
1999年FCC对E-911法进行修订
- 欧洲于2003年1月1日开始实施“US FCC”标准——建议使用E-OTD即“增强型观测时间差”技术



□ 商业公司

- 定位服务(TAGGING)、追踪服务(TRACKING)、导航服务(TRACING)等





LBS应用分类

□ 面向用户 LBS

□ Push服务

□ 面向设备 LBS

□ Pull服务

	Push服务	Pull服务
面向用户服务	当你进入某城市时接到欢迎信息	请求查找最近邻餐馆
面向设备服务	在货物追踪应用中，当货物运送偏离预计轨道时给与警报信息	请求查找卡车现在所在位置



LBS与隐私

□ 欧洲委员会

Directive 2002/58/EC 条款9

- Location data may only be processed when it is made anonymous OR with the consent of the user for the duration necessary for the provision of a service(位置数据只有在匿名或用户同意的前提下为有效并必要的服务使用).

□ Vodafone UK制定了一套隐私管理业务条例(privacy management code of practice),要求所有为Vodafone客户提供服务的第三方必须遵守



32002L0058

Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector (Directive on privacy and electronic communications)

Official Journal L 201, 21/07/2002 P. 0037 - 0047

Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector (Directive on privacy and electronic communications)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 95 thereof,

Having regard to the proposal from the Commission(1),

Having regard to the opinion of the Economic and Social Committee(2),

Having consulted the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty(3),

Whereas:

(1) Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data(4) requires Member States to ensure the rights and freedoms of natural persons with regard to the processing of personal data, and in particular their right to privacy, in order to ensure the free flow of personal data in the Community.

(2) This Directive seeks to respect the fundamental rights and observes the principles recognised in particular by the Charter of fundamental rights of the European Union. In particular, this Directive seeks to ensure full respect for the rights set out in Articles 7 and 8 of that Charter.

(3) Confidentiality of communications is guaranteed in accordance with the international instruments relating to human rights, in particular the European Convention for the Protection of Human Rights and Fundamental Freedoms, and the constitutions of the Member States.

(4) Directive 97/66/EC of the European Parliament and of the Council of 15 December 1997 concerning the processing of personal data and the protection of privacy in the telecommunications sector(5) translated the principles set out in Directive 95/46/EC into specific rules for the telecommunications sector. Directive 97/66/EC has to be adapted to developments in the markets and technologies for electronic communications services in order to provide an equal level of protection of personal data and privacy for users of publicly available electronic communications services, regardless of the technologies used. That Directive should therefore be repealed and replaced by this Directive.

(5) New advanced digital technologies are currently being introduced in public communications networks in the Community, which give rise to specific requirements concerning the protection of personal data and privacy of the user. The development of the information society is characterised by the introduction of new electronic communications services. Access to digital mobile networks has become available and affordable for a large public. These digital networks have large capacities and possibilities for processing personal data. The successful cross-border development of these services is partly dependent on the confidence of users that their privacy will not be at risk.

(6) The Internet is overturning traditional market structures by providing a common, global infrastructure for the delivery of a wide range of electronic communications services. Publicly available electronic communications services over the Internet open new possibilities for users but also new risks for their personal data and privacy.

(7) In the case of public communications networks, specific legal, regulatory and technical provisions should be made in order to protect fundamental rights and freedoms of natural persons and legitimate interests of legal persons, in particular with regard to the increasing capacity for automated storage and processing of data relating to subscribers and users.

(8) Legal, regulatory and technical provisions adopted by the Member States concerning the protection of personal data, privacy and the legitimate interest of legal persons, in the electronic communications sector, should be harmonised in order to avoid obstacles to the internal market for electronic communication in accordance with Article 14 of the Treaty. Harmonisation should be limited to requirements necessary to guarantee that the promotion and development of new electronic communications services and networks between Member States are not hindered.

(9) The Member States, providers and users concerned, together with the competent Community bodies, should cooperate in introducing and developing the relevant technologies where this is necessary to apply the guarantees provided for by this Directive and taking particular account of the objectives of minimising the processing of personal data and of using anonymous or pseudonymous data where possible.

(10) In the electronic communications sector, Directive 95/46/EC applies in particular to all matters concerning protection of fundamental rights and freedoms, which are not specifically covered by the provisions of this Directive, including the obligations on the controller and the rights of individuals. Directive 95/46/EC applies to non-public communications services.

(11) Like Directive 95/46/EC, this Directive does not address issues of protection of fundamental rights and freedoms related to activities which are not governed by Community law. Therefore it does not alter the existing balance between the individual's right to privacy and the possibility for Member States to take the measures referred to in Article 15(1) of this Directive, necessary for the protection of public security, defence, State security (including the economic well-being of the State when the activities relate to State security matters) and the enforcement of criminal law. Consequently, this Directive does not affect the ability of Member States to carry out lawful interception of electronic communications, or take other measures, if necessary for any of these purposes and in accordance with the European Convention for the Protection of Human Rights and Fundamental Freedoms, as interpreted by the



LBS中的隐私泄露

□ 位置隐私泄露

- 位置，包括用户过去或现在的位置

□ 查询隐私泄露

- 查询内容，例如查询距离我最近的艾滋医院

行为模式、兴趣爱好、健康状况和政治倾向等
个人隐私信息



LBS中隐私保护

- 位置隐私保护
 - 避免用户与某一精确位置匹配

- 查询隐私保护
 - 避免用户与某一敏感查询匹配



位置服务 VS 隐私保护

□ 位置服务

- 提供精确位置

□ 隐私

- 模糊用户的位置

鱼与熊掌可否兼得？





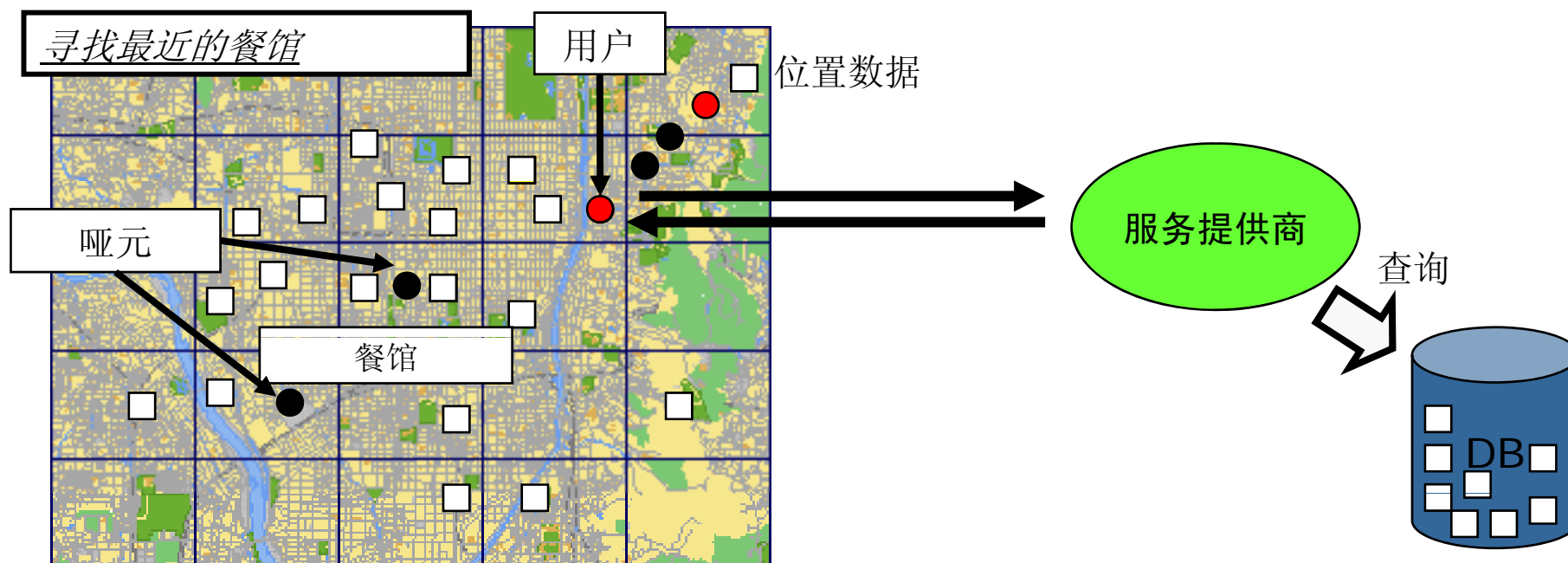
隐私保护的方法

- 假位置 (Dummy)
- 时空匿名 (Spatio-temporal Cloaking)
- 空间加密 (Space Encryption)



隐私保护的基本方法--假位置

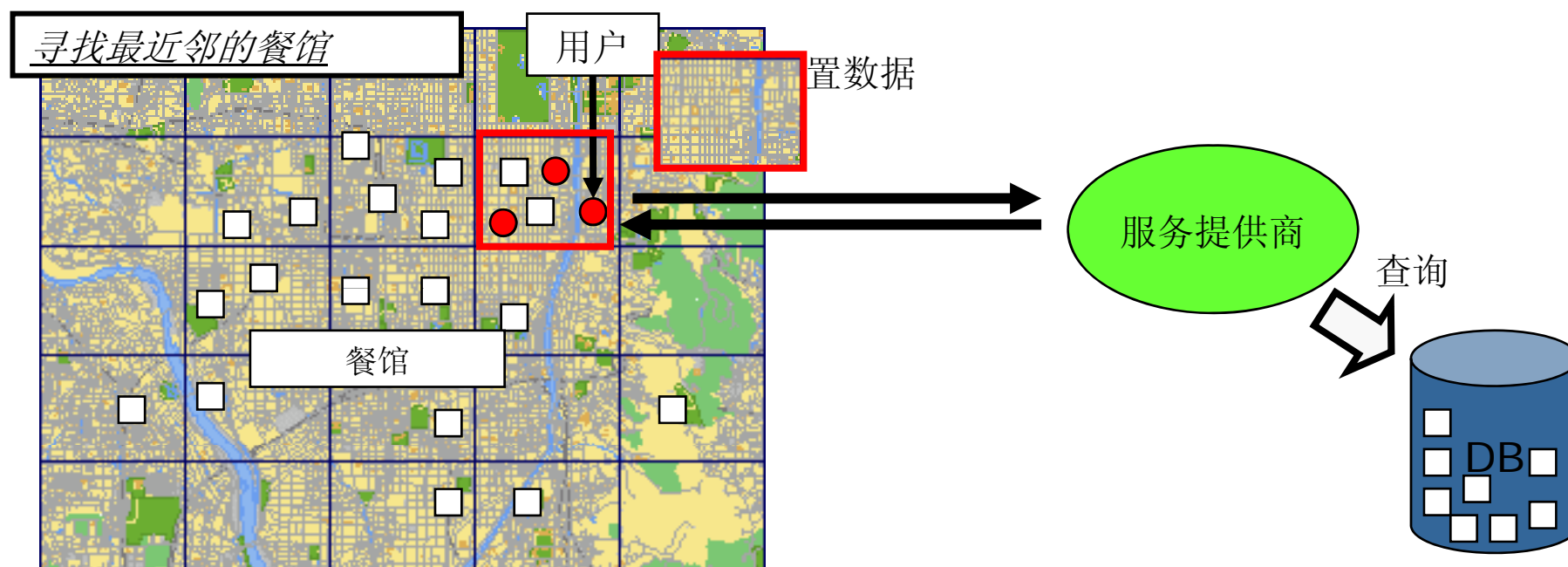
□ 通过制造假位置，达到以假乱真的效果





隐私保护的基本方法--时空匿名

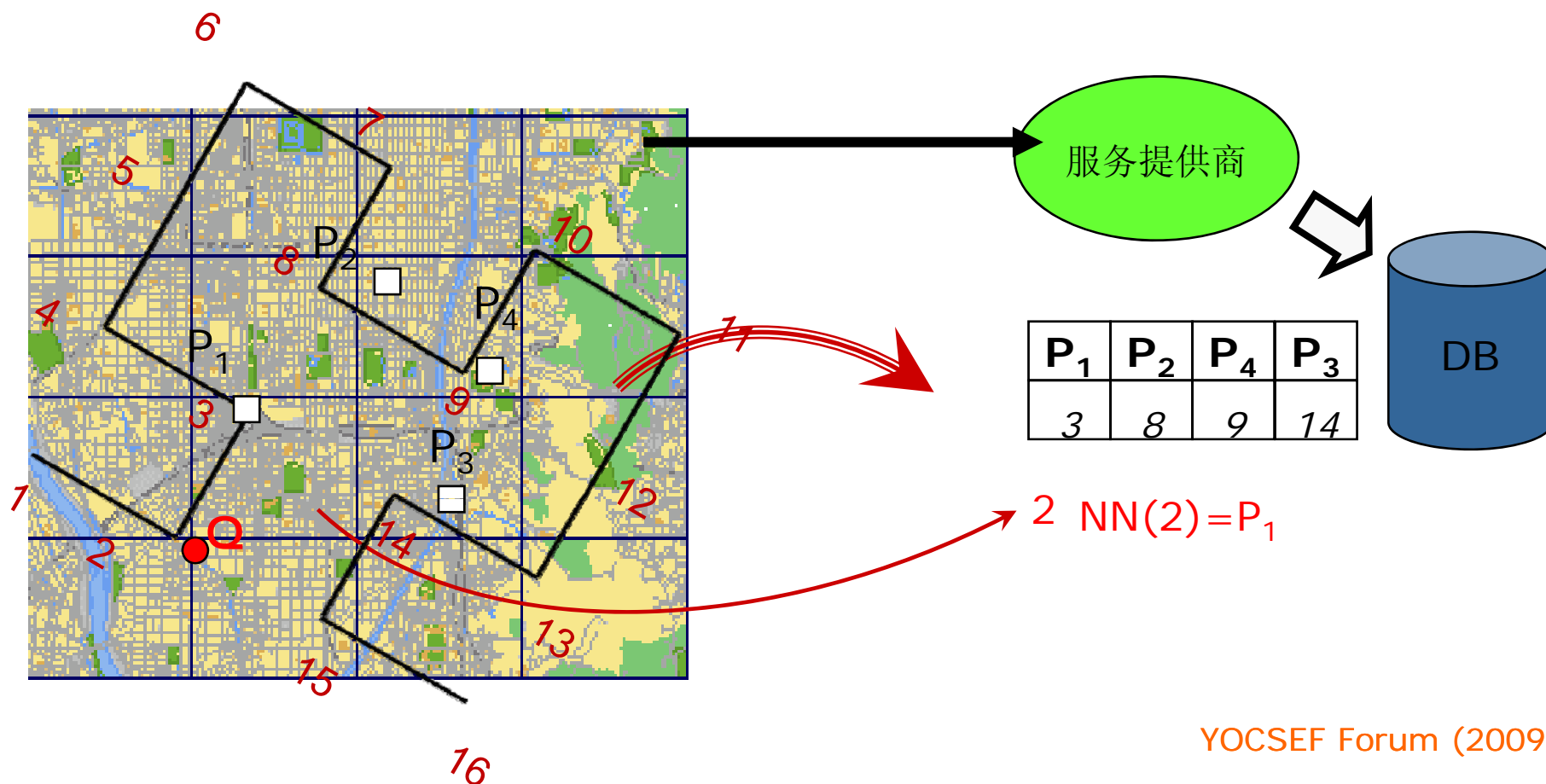
- 将一个用户的位置通过扩展变成时空区域，达到匿名的效果





隐私保护的基本方法—空间加密

□ 通过对位置加密从而达到匿名的效果





感知隐私保护的查询处理

假数据

- 移动对象数据库中的查询处理器无需作任何修改

时空匿名

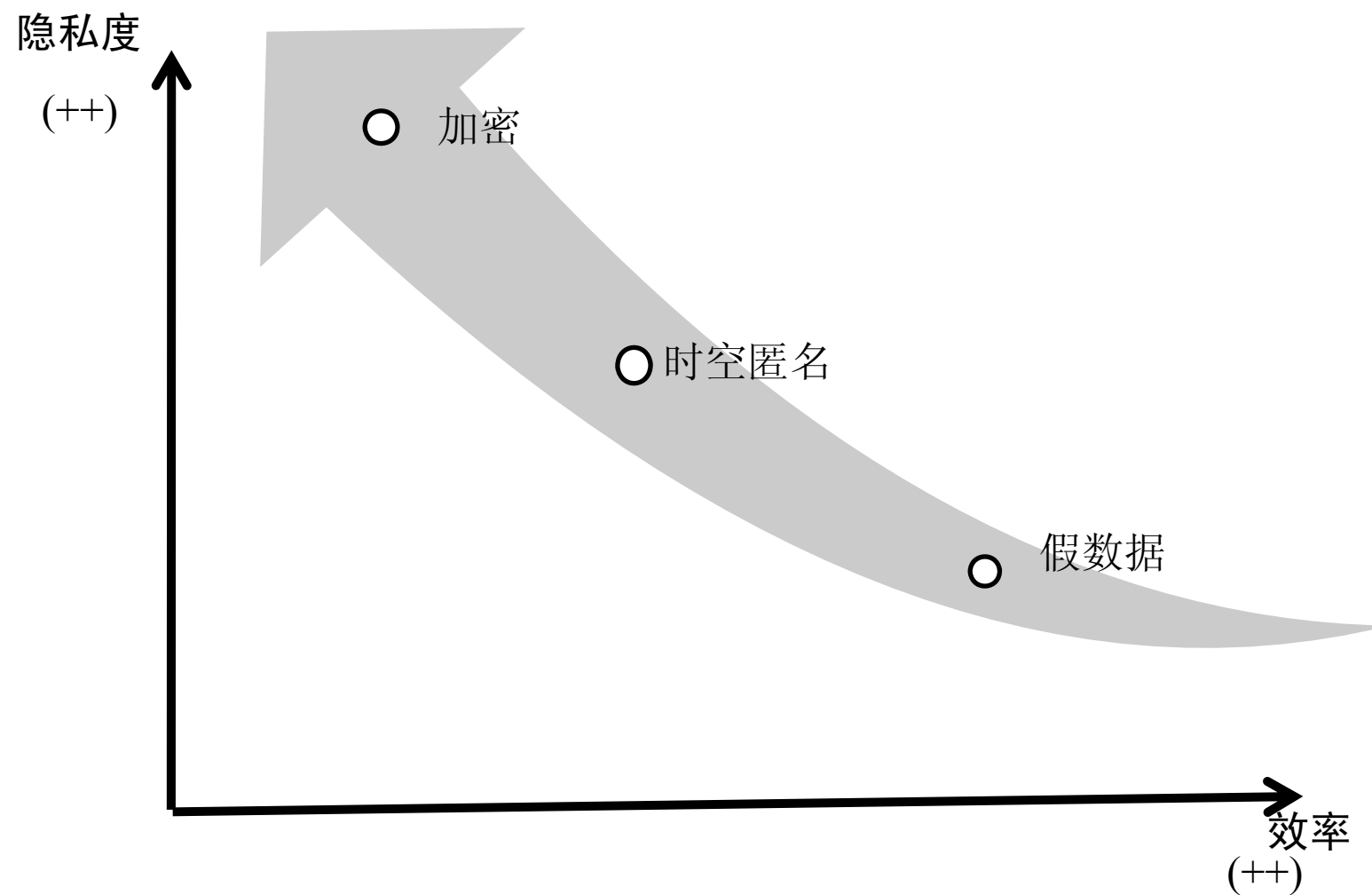
- 设计基于区域位置的查询处理技术；查询结果是一个包含真实结果的超集

空间加密

- 查询方法与使用的加密协议有关



隐私度与效率对比





存在的挑战



保护隐私与位置服务是一对矛盾



位置匿名的即时性



位置频繁更新以及位置依赖性



隐私需求个性化

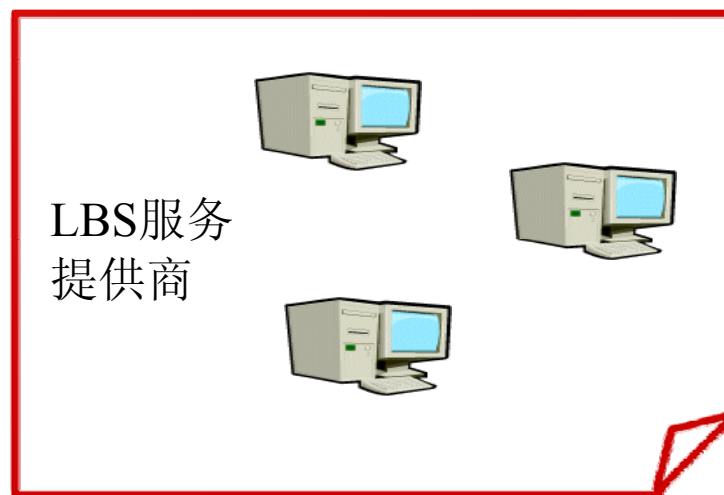
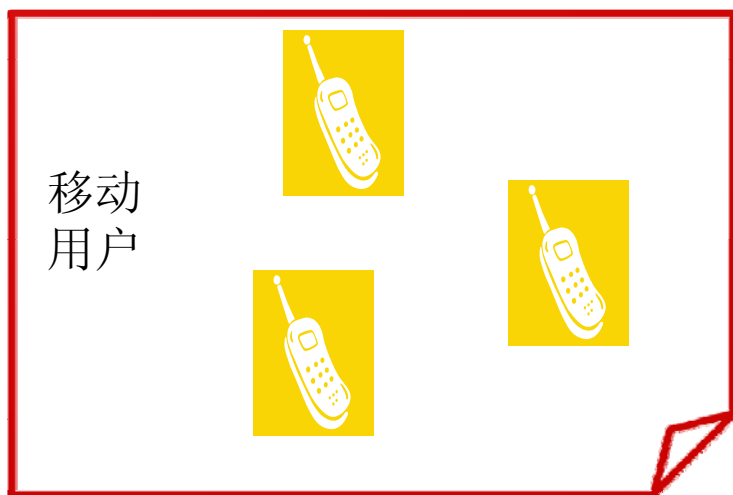


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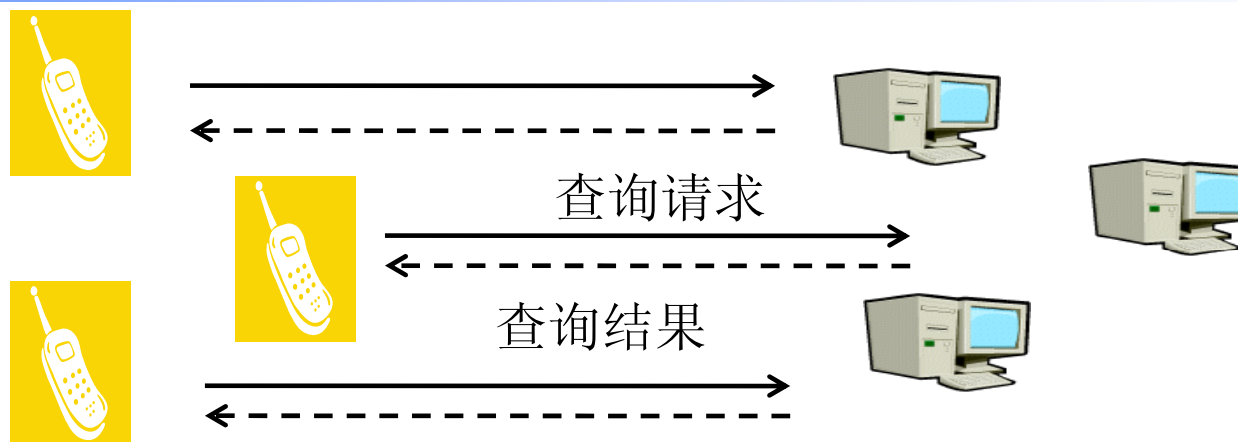
隐私保护系统结构



- ❑ 独立式结构
- ❑ 中心服务器结构
- ❑ 分布式结构
- ❑ 点对点结构



隐私保护系统结构-独立式结构



□ 优点

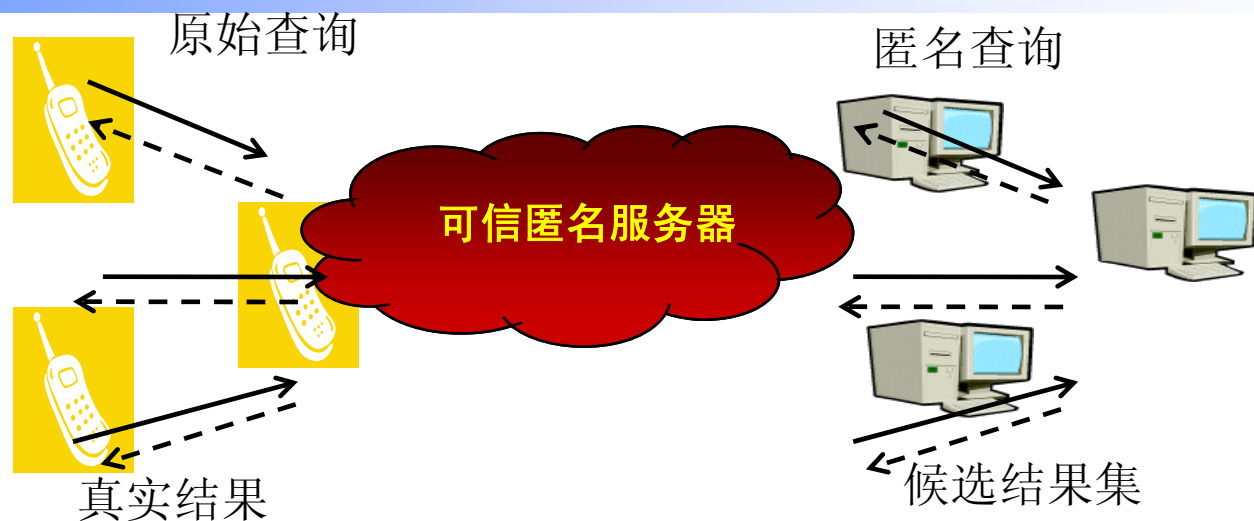
- 结构简单，易于配置

□ 缺点

- 增加客户端负担
- 缺乏全局信息，隐蔽性弱



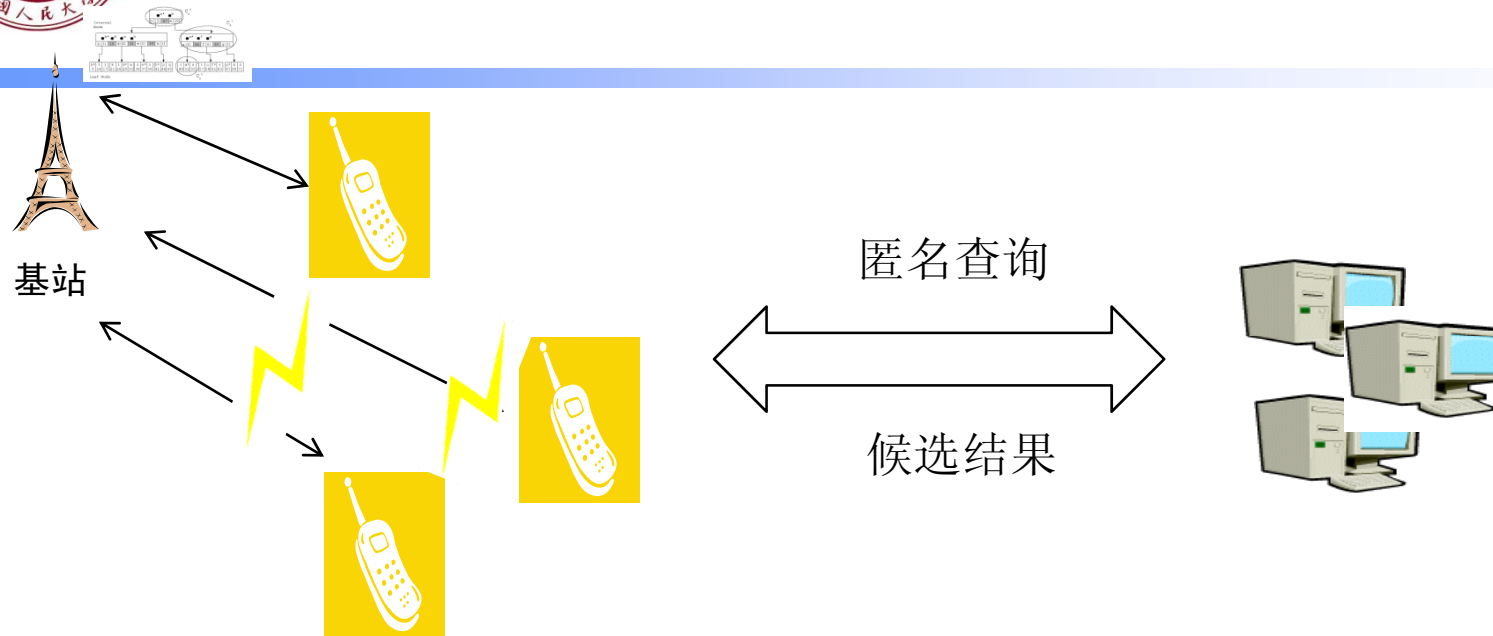
隐私保护系统结构-中心服务器结构



- 优点
 - 具有全局信息，隐私保护效果好
- 缺点
 - 可能成为系统瓶颈
 - 唯一攻击点



隐私保护系统结构-主从分布式结构



□ 优点

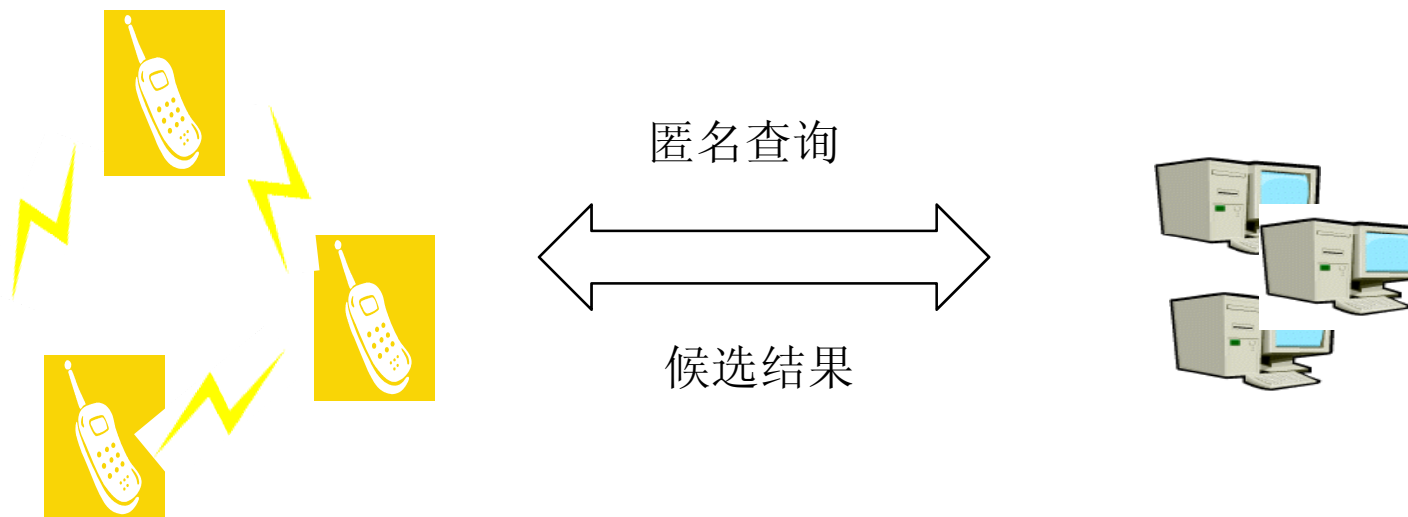
- 拥有全局信息，隐私效果好
- 消除了系统瓶颈

□ 缺点

- 网络通讯代价高



隐私保护系统结构-移动点对点结构



- 优点
 - 拥有全局信息，隐私效果好
 - 消除唯一攻击点
- 缺点
 - 网络通讯代价高



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隐私保护研究内容

□ 隐私保护方法

- 位置隐私保护方法
- 查询隐私保护方法

□ 感知隐私的查询处理

- 基于区域位置的查询处理技术
- 基于加密位置的查询处理技术



隐私保护模型

隐私保护方法

- 位置隐私方法
- 查询隐私方法
- 感知隐私的查询处理
- 基于区域位置

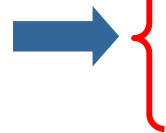
□ 位置 k -匿名

□ 当且仅当一个用户的位置与其他 $(k-1)$ 个用户的位置无法区别时，称该用户满足位置 k -匿名



原始查询

位置	查询
(1, 6)	Q_1
(1, 5)	Q_2
(2, 9)	Q_3
...	...



匿名后查询

匿名位置	查询
$[(1,2)-(5, 9)]$	Q_1
$[(1,2)-(5, 9)]$	Q_2
$[(1,2)-(5, 9)]$	Q_3
...	...

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基于四分树的隐私保护方法 (Quadtree based Cloaking)

隐私保护方法

— 位置隐私方法
— 查询隐私方法

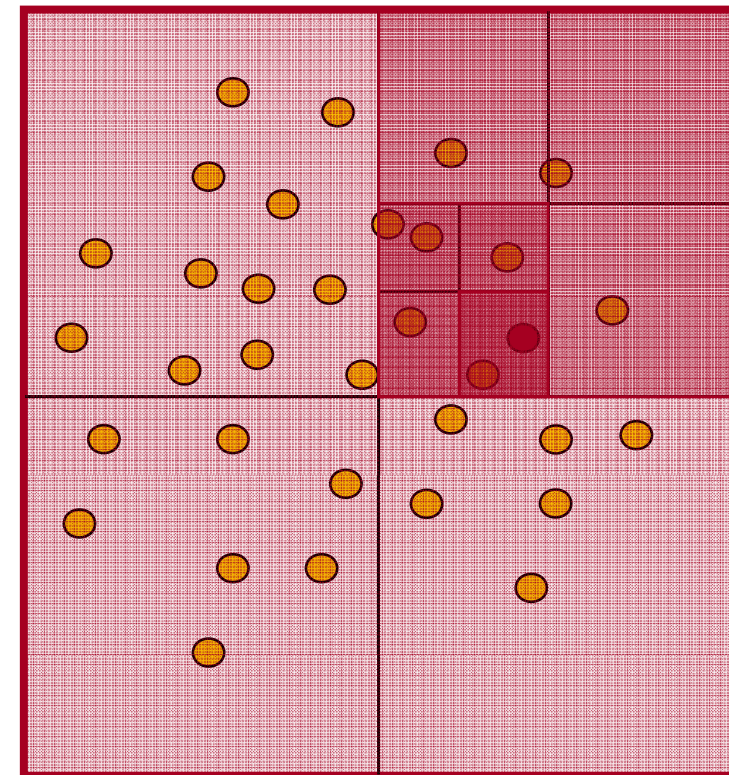
感知隐私的查询处理
— 基于区域位置

□ 问题

- 面对大量移动用户，如何快速高效的为移动用户寻找匿名集

□ 解决方法

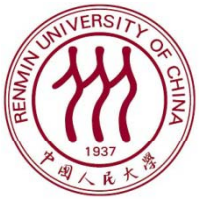
- 递归式的划分空间，直至在某子空间内的用户数小于 k ，则返回其上一级的子空间作为位置匿名区域



$K=3$

M. Gruteser, D. Grunwald. Anonymous usage of location-based services through spatial and temporal cloaking. Proceedings of the International Conference on Mobile Systems, Applications, and Services (MobiSys'03), San Francisco, USA, 2003:163–168.

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个性化隐私需求匿名方法 (CliqueCloak)

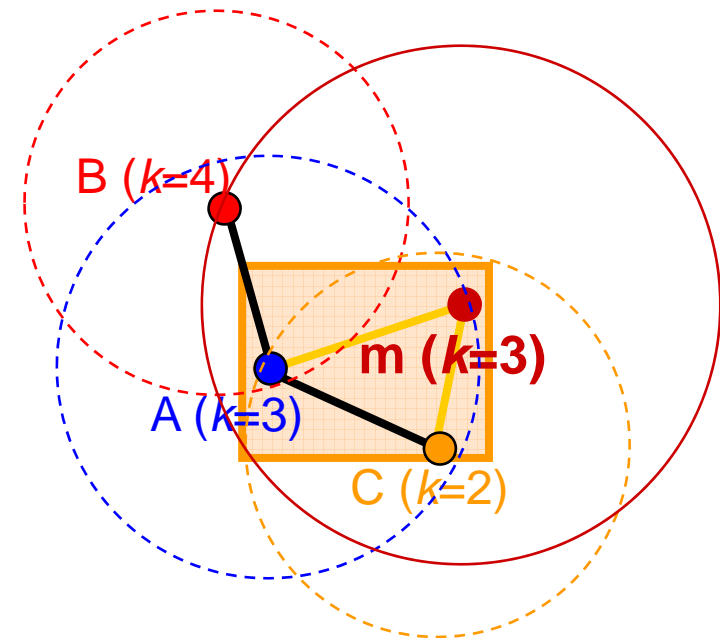
隐私保护方法
├ 位置隐私方法
├ 查询隐私方法
└ 感知隐私的查询处理
└ 基于区域位置

□ 问题

- 如何为每一个用户提供满足个性化隐私需求的匿名

□ 解决方法

- 利用图模型形式化的定义此问题，并把寻找匿名集转化为在图中寻找 k -点团的问题



Gedik B, Liu L. Location privacy in mobile systems: a personalized anonymization model. Proceeding of the International Conference on Distributed Computing Systems(ICDCS'05), Columbus, OH, USA, 2005: 620–629

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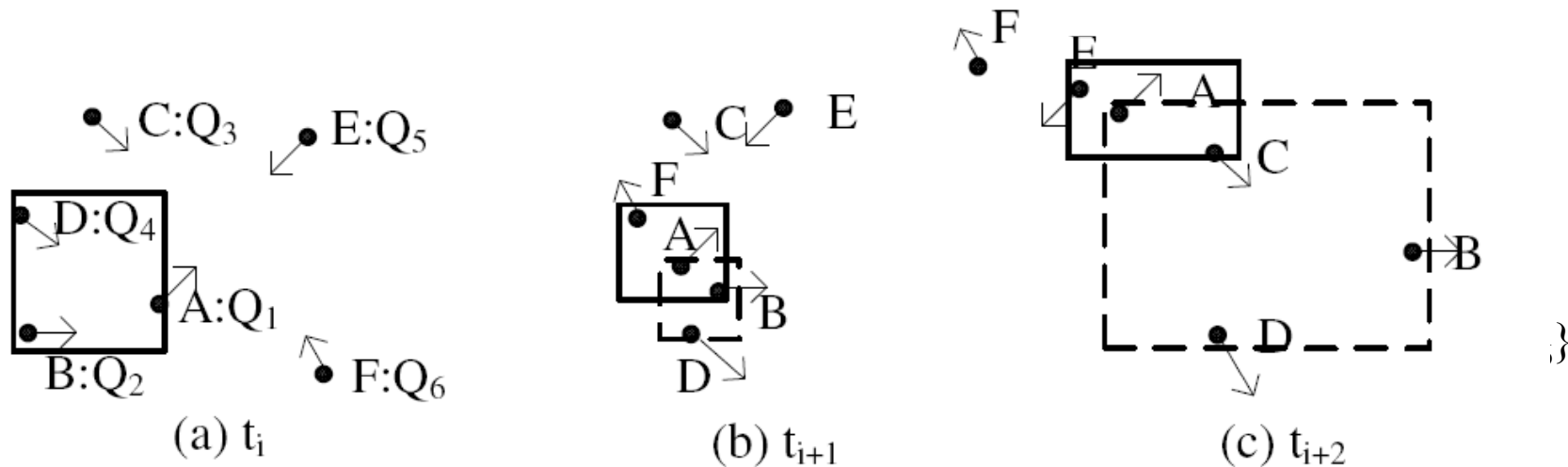
连续查询隐私保护技术

(C.Chow and M. F. Mokbel, 2007)

隐私保护方法
— 位置隐私方法
— 查询隐私方法
感知隐私的查询处理
— 基于区域位置

□ 问题

- 位置服务中现有的隐私保护工作均针对 *snapshot* 查询类型



□ 解决方法

- 连续查询的用户在最初时刻形成的匿名集在其查询有效期内均有效。

C. Chow and M. F. Mokbel. Enabling privacy continuous queries for revealed user locations.
In *Proceedings of SSTO*, 2007

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感知查询差异性的隐私保护 (*p*-sensitive)

隐私保护方法
— 位置隐私方法
— 查询隐私方法
感知隐私的查询处理
— 基于区域位置

□ 问题

- 位置 k -匿名只能防止用户与查询间的关联，但不能切断用户与查询内容的关联
- 缺少语义的匿名，将产生查询隐私泄露的现象

Location	Query
[(1,2)-(5, 9)]	Hospital
[(1,2)-(5, 9)]	Clinic
[(1,2)-(5, 9)]	Hospital
[(2,5)-(4, 7)]	Gas Station
[(2,5)-(4, 7)]	Gas Station
[(2,5)-(4, 7)]	School

Location	Query
[(1,2)-(4, 7)]	** Club A
[(1,2)-(4, 7)]	Gas Station
[(1,2)-(4, 7)]	Gas Station
[(5,2)-(7, 9)]	Restaurant
[(5,2)-(7, 9)]	Clinic
[(5,2)-(7, 9)]	School

□ 解决方法

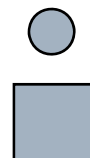
- 考虑查询语义
- 一个匿名集中所包含的敏感查询不能超过 $p\%$

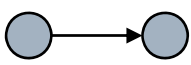
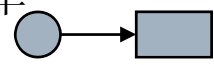
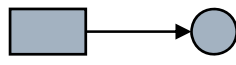
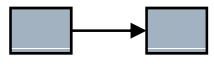


感知隐私保护的查询处理

隐私保护方法
├ 位置隐私方法
├ 查询隐私方法
└ 感知隐私的查询处理
 ├ 基于区域位置

- 如何在位置被区域匿名后提供令用户满意的服务
- 两种位置数据类型：
 - 公开位置数据. 如加油站、旅馆和警车
 - 隐私位置数据. 如个人位置

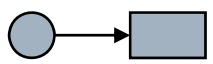


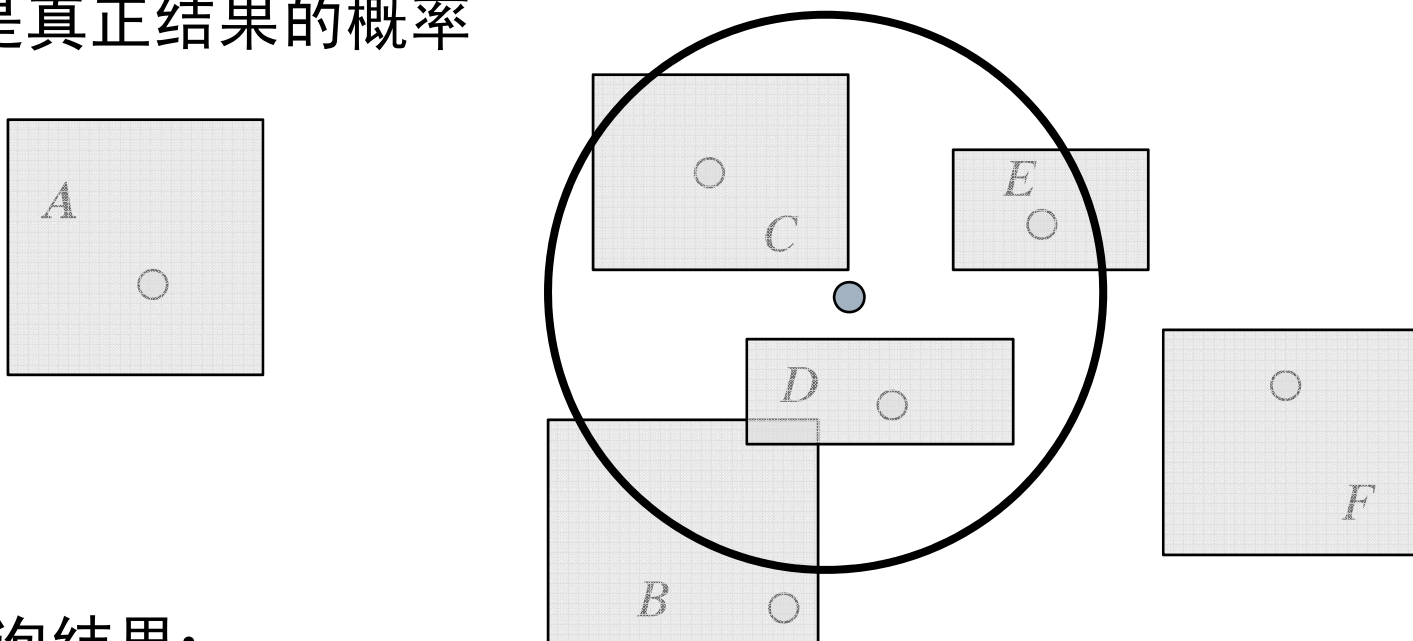
查询类型		被查询点	
		公开数据	隐私数据
查询点	公开数据	基于公开数据的公开查询 如：在某电影院200m内所有餐馆 	基于隐私数据的公开查询 如：某加油站500米内所有出租车 
	隐私数据	基于公开数据的隐私查询 如：距离我最近的加油站 	基于隐私数据的隐私查询 如：离我最近的朋友 



基于隐私数据的公开查询

隐私保护方法
├ 位置隐私方法
├ 查询隐私方法
感知隐私的查询处理
├ 基于区域位置

- ❑ “某加油站500米内所有出租车” 
- ❑ 将所有与查询范围相交的匿名区域都作为候选集。
- ❑ 根据匿名框与矩形框的重叠区域面积大小表示查询结果是真正结果的概率



查询结果:

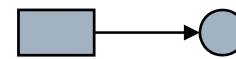
■ (B, 50%), (C, 90%), (D, 1), (E, 60%)



基于隐私数据的公开查询

隐私保护方法
— 位置隐私方法
— 查询隐私方法
感知隐私的查询处理
— 基于区域位置

□ “距离我最近的加油站”

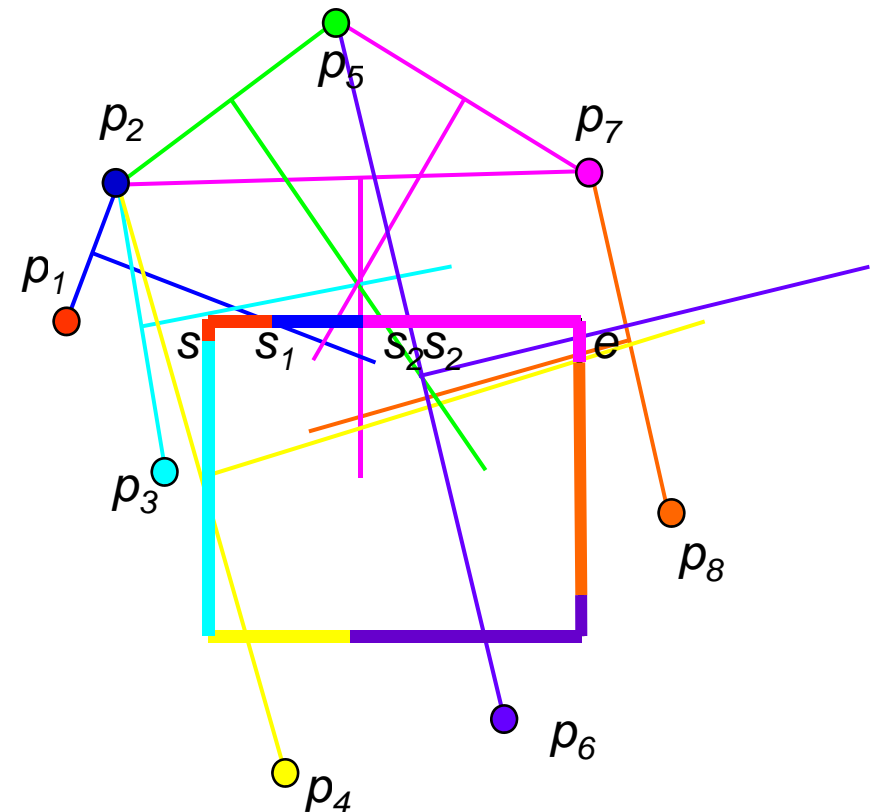


□ 查找匿名区域中任意一个位置的最近邻

■ 查找匿名框所覆盖的对象

■ 查找基于每一条边上的任意点的最近邻

■ 二者的并作为最终的查询结果返回



YOCSEF Forum (2009.12)



报告大纲

- 隐私保护问题及意义
- 隐私保护系统结构
- 隐私保护研究内容
- 隐私保护面临挑战
- 总结



隐私保护技术面临的问题

- ❑ 多技术混合的隐私保护
- ❑ 移动对象轨迹的隐私保护
- ❑ 室内位置隐私保护



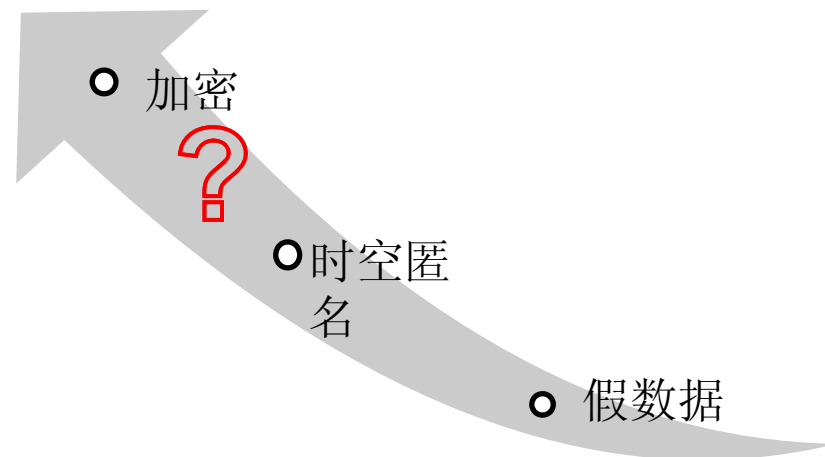
多技术混合的隐私保护

□ 问题

- 加密安全但查询代价高，时空匿名高效但不够安全

□ 研究结合加密算法高隐私保护度，空间匿名算法的高效率的混合匿名模型和算法

□ 研究基于混合匿名的感知隐私的查询处理算法





移动轨迹的隐私保护

□ 问题

- 轨迹发布而产生的隐私泄露

□ 研究基于时空匿名的轨迹匿名模型和算法

□ 研究在线轨迹匿名模型和算法

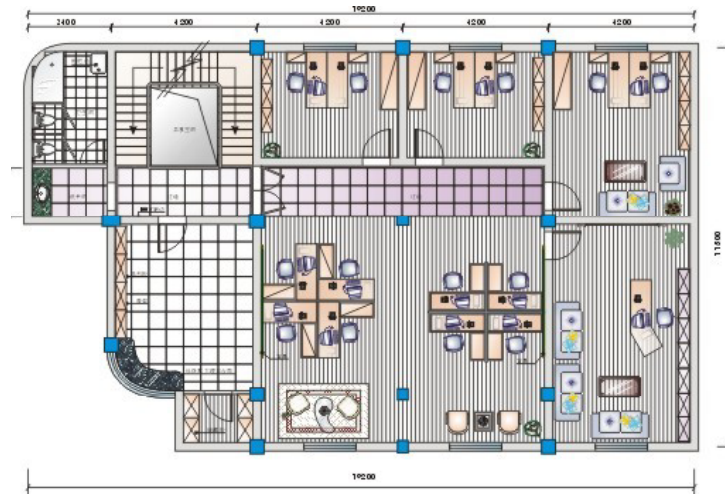




室内位置隐私

□ 问题



- 室内安装无限传感器收集用户位置用于安全控制、资源管理等
- 室内提出的查询多位密度查询或聚类查询



- ## □ 研究基于室内位置隐私的攻击模型、匿名模型、匿名算法和查询处理算法



可能的解决方法



数据发布中的隐私保护技术

移动对象的查询处理技术

不确定数据的建模、查询处理技术





报告大纲

- 隐私保护问题及意义
- 隐私保护系统结构
- 隐私保护研究内容
- 隐私保护面临挑战
- 总结



在研课题-隐私保护技术

□ 国家863计划重点项目

“普适计算基础软硬件关键技术及系统”项目中“
隐私保护技术”课题

□ 研究目标

- 在普适计算以人为中心的理念下，针对个人信息隐私、位置隐私和查询隐私等问题从模型、算法和评价等方面展开研究，开发可配置的分级隐私保护模块，为构建相应示范应用提供支持



在研课题-隐私保护技术





在研课题-隐私保护技术

□ 系统界面

隐私保护展示 - Windows Internet Explorer

http://localhost:8080/flex-map/main.html

隐私保护展示

参数配置

移动数据: 人民大学

服务类型: 一般位置保护

地图导入 (基于Google Maps)

服务质量显示

服务质量参数

服务参数	其他信息
类型	值
服务方法	一般位置隐私保护
服务描述	一般位置隐私保护算法
所用时间	0
其他信息	

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完成

Internet | 保护模式: 禁用

(2009.12)



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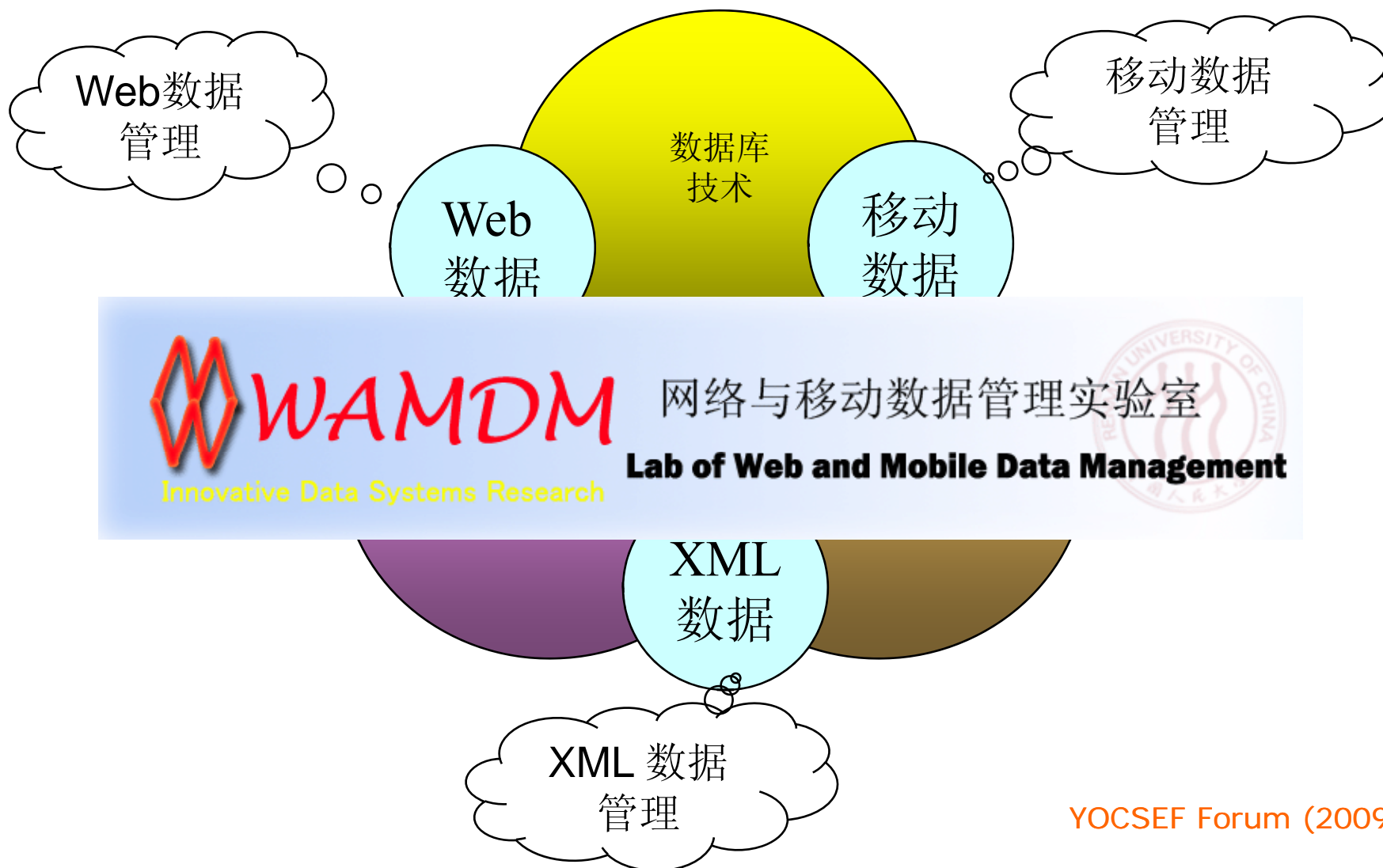


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研究团队





谢谢