Privacy-Preserving Publication of User Locations in the Proximity of Sensitive Sites

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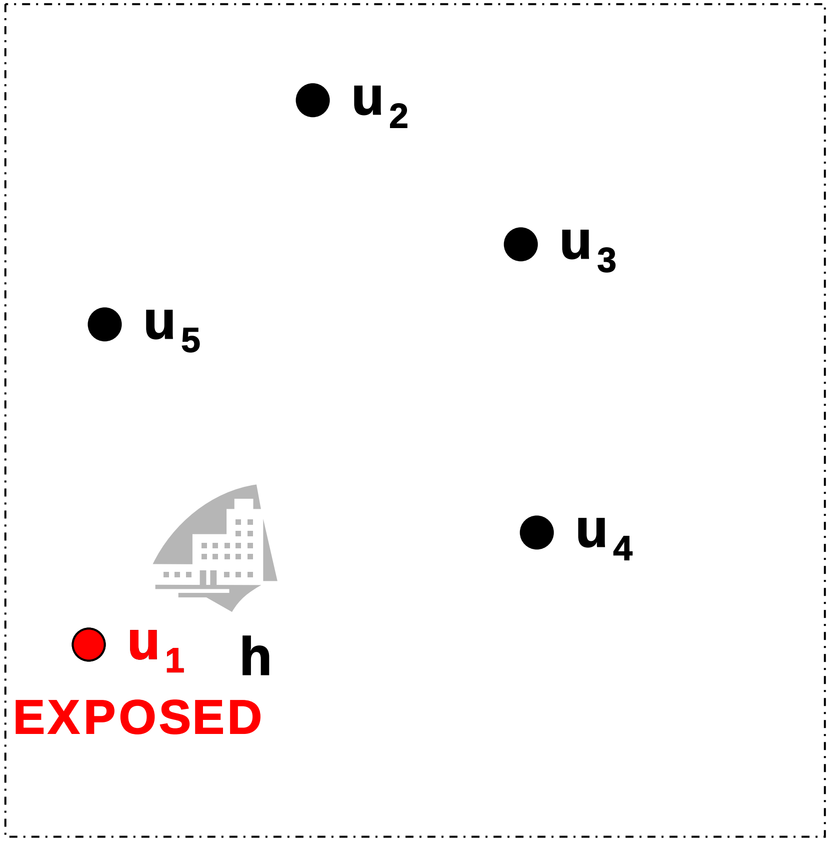
Privacy Threat

Hu et al., “Privacy Aware Location Publishing for Moving Clients”



Location Publishing

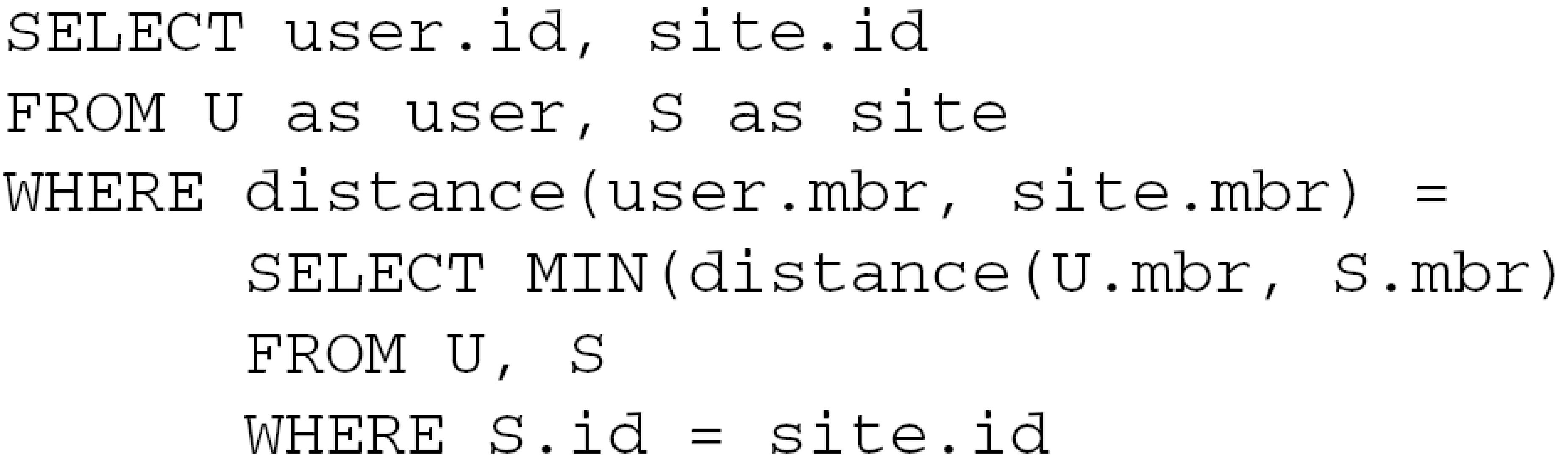
- Traffic congestion control
- Infrastructure planning
- Snapshot at 2pm

Hospital Data (external)

Time	*Specialty*
01:00 PM	Dentistry
02:00 PM	Cardiology
04:00 PM	Surgery

Attack

- Attack: Associate a site ***s*** with fewer than **K** users

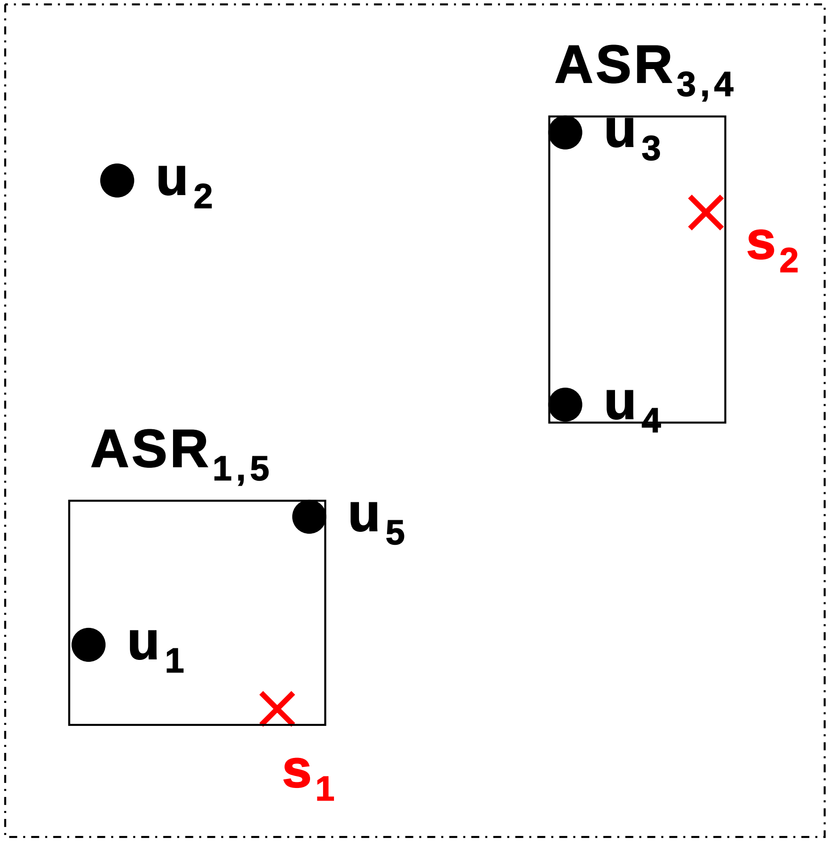


```
SELECT user.id, site.id
FROM U as user, S as site
WHERE distance(user.mbr, site.mbr) =
      SELECT MIN(distance(U.mbr, S.mbr)
      FROM U, S
      WHERE S.id = site.id
```

- Attack is successful in the previous slide:

< u_1, h >

Solution Outline (*K*-anonymity)



- Attack, K=2

<u1, s1>

<u5, s1>

<u3, s2>

<u4, s2>

NOT successful

Problem Statement

- User set *U*, sensitive sites set *S*
- Mapping *M:S -> 2^U*

$$\forall s \in S, |M(s)| = K$$

$$\forall s_1, s_2 \in S, M(s_1) \cap M(s_2) = \varnothing$$

- Minimize Generalization Cost **(GGC)**

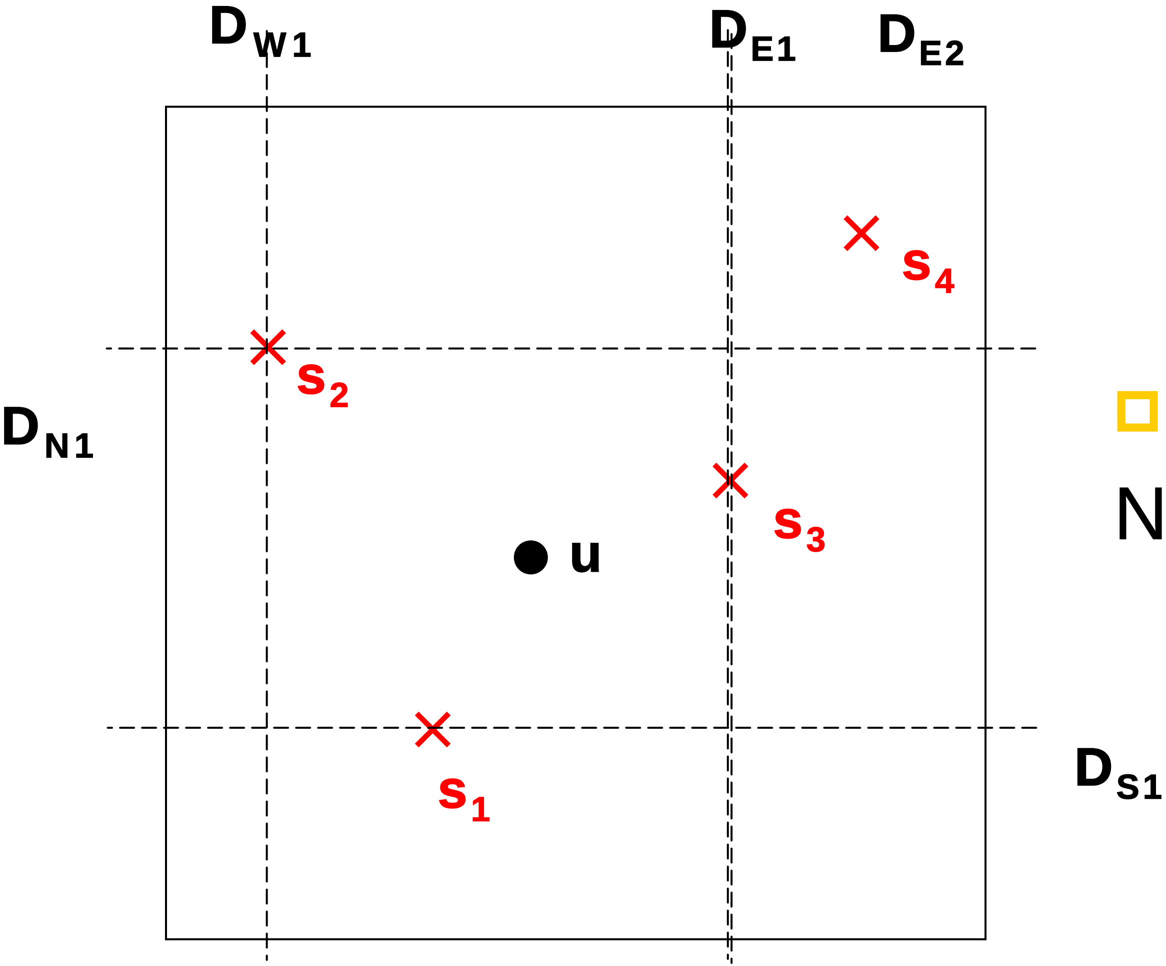
$$GGC(M) = \sum_{s \in S} Area(MBR(\{s\} \cup M(s)))$$

Related work: Query Privacy in LBS

- Relies on Spatial K-anonymity as well
  - Gedik & Liu, ICDCS ’05
  - Mokbel et al., VLDB ’06
  - Kalnis et al., TKDE ’07
  - ...
- But anonymizes a **single** query
  - Equivalent to |S|=1
- In our problem |S|>>1
  - More difficult to solve

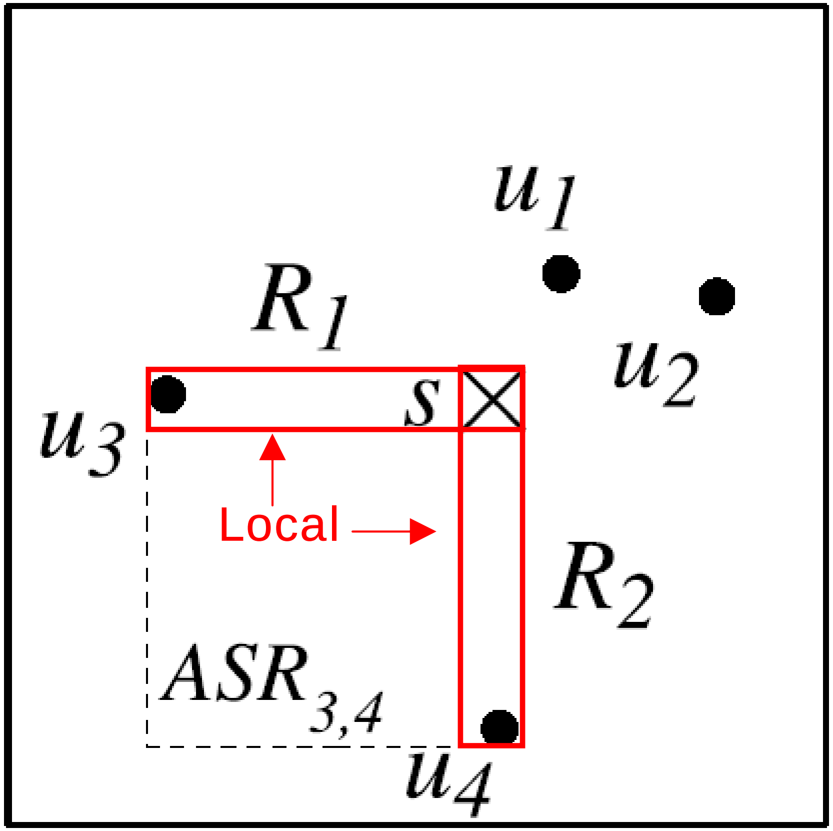
Related work: “Local” algorithm

[HXD+07] Hu H., Xu J., Du J., Ng J.K.Y., “Privacy Aware Location Publishing for Moving Clients”, TR, Hong Kong Baptist Univ., 2007 www.comp.hkbu.edu.hk/~haibo/privacy_join.pdf



- Benefit: NumOfSites/Area

Drawback of Local's Publication Format



2-by-2 publishing

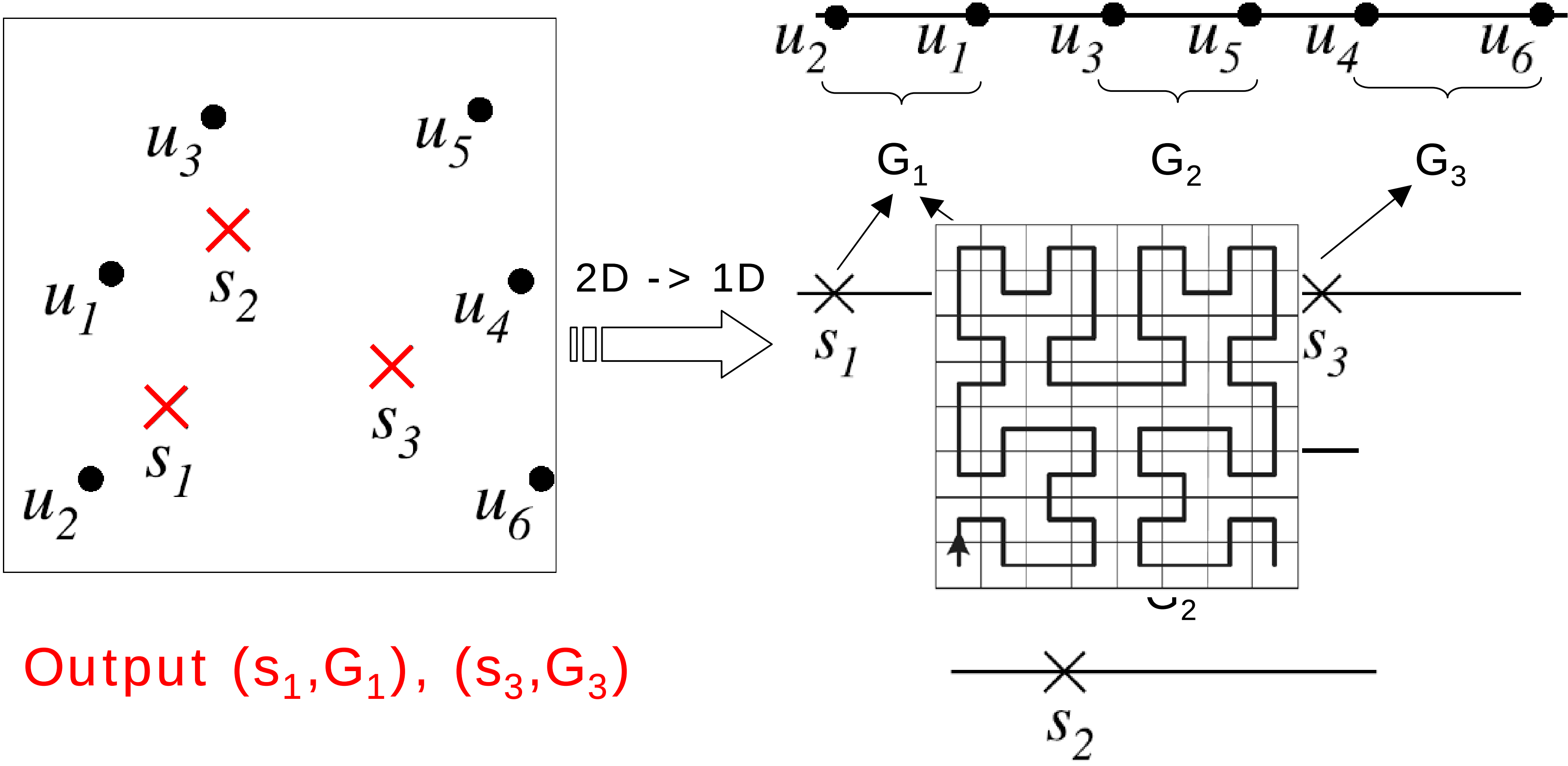
Our Approach
MK: Monochromatic *K*-anonymity

- Phase 1:
  - Transform user locations to 1D
  - Anonymization w.r.t. user set *U* ONLY
  - Linear algorithm*, 1-D optimal
  - User groups independent of sites *S*

- Phase 2:
  - Assign each anonymous group to nearest site
  - Resolve potential conflicts
    - E.g., choose assignment with minimum enlargement
  - Repeat until all sites are covered

[GKKM07] Ghinita G., Karras P., Kalnis P., Mamoulis N. “Fast Data Anonymization with Low Information Loss”. In Proc. of VLDB 2007

MK Example



Output (s_1,G_1), (s_3,G_3)

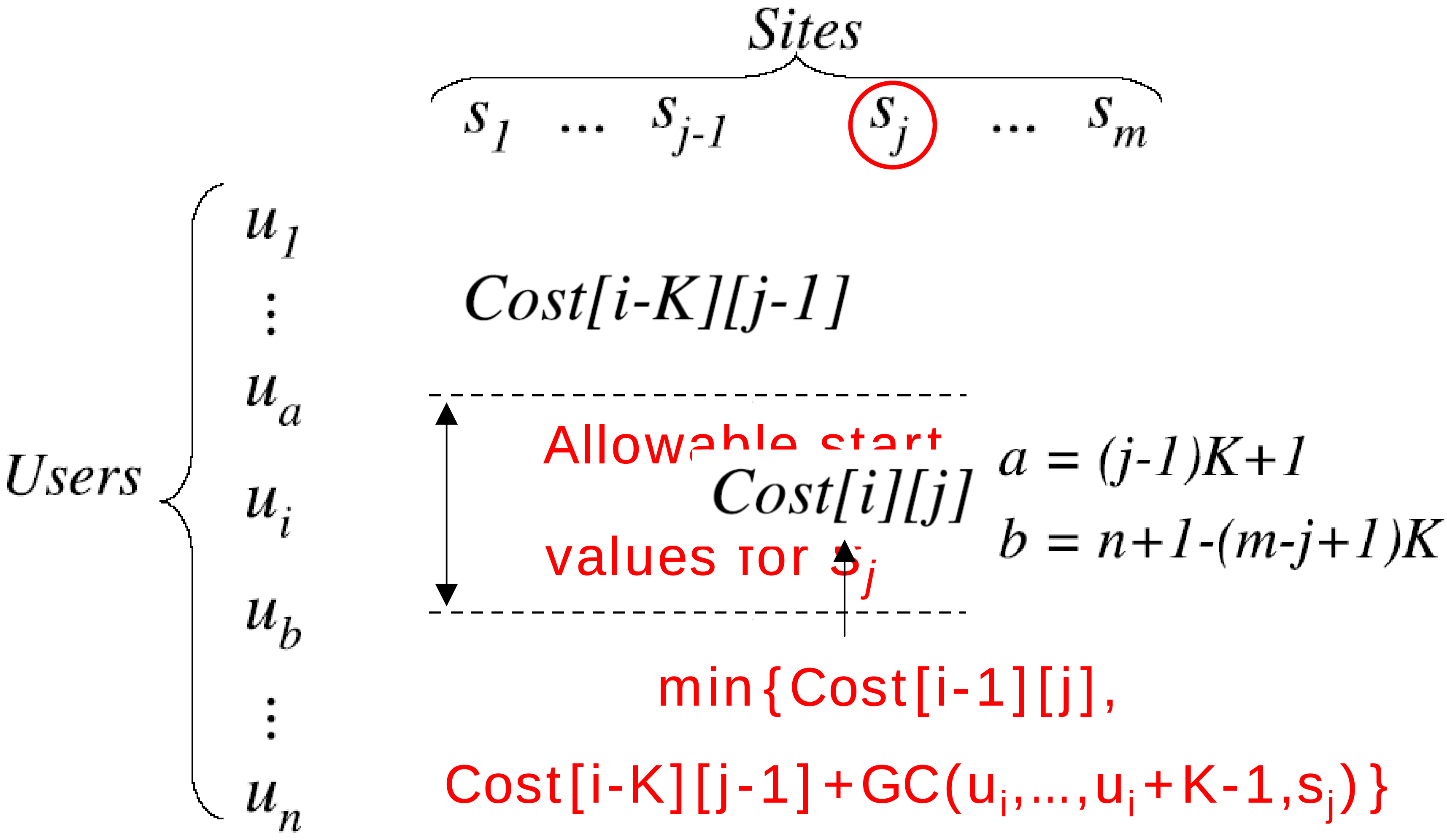
Output (s_2,G_2)

Our Approach
BK: Bichromatic *K*-anonymity

- Properties of optimal mapping in 1-D
  1. Each ASR/group has exactly *K* users
  2. ASRs have consecutive users in 1-D order
  3. Groups do not overlap in 1-D order

- Bichromatic clustering of U and S
  - Each cluster has 1 site and *K* users
  - DP algorithm, linear in *K* and |*U*|

BK Example



Allowable start values for s_j

$a = (j-1)K+1$

$b = n+1-(m-j+1)K$

min{Cost[i-1][j],

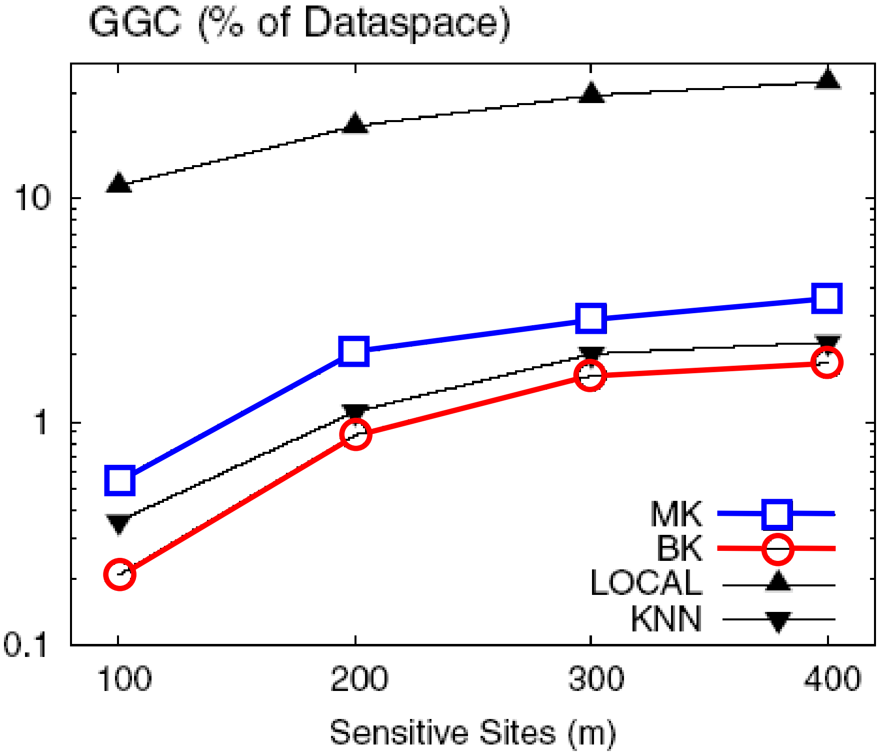
Cost[i-K][j-1]+GC(u_i,…,u_i+K-1,s_j)}

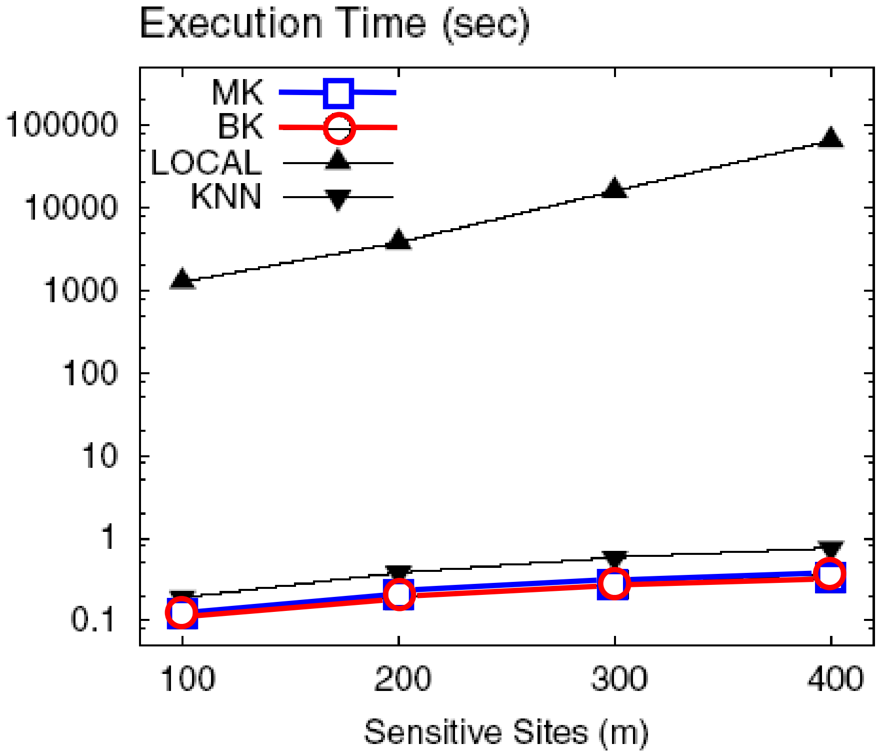
Experimental Evaluation

- Naïve competitor: **K-Nearest-Neighbors**
- NA Dataset (569120 locations)
  - *U* and *S* randomly sampled from NA
- Performance metrics:
  - Anonymization overhead (CPU time)
  - Generalization Cost

$$GGC(\mathcal{M}) = 100 \cdot \frac{\sum_{s \in S} Area(MBR(\mathcal{M}(s) \cup \{s\}))}{DomainArea}\%$$

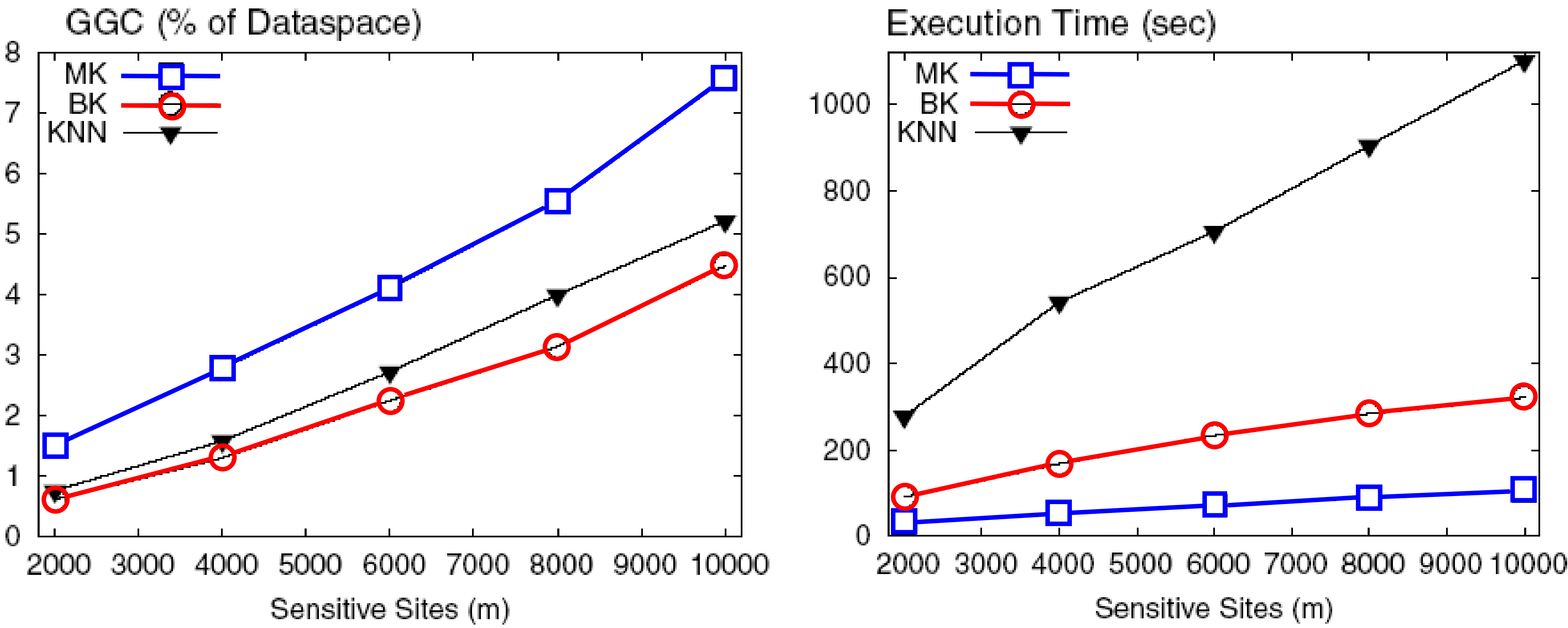
Comparison with “Local”





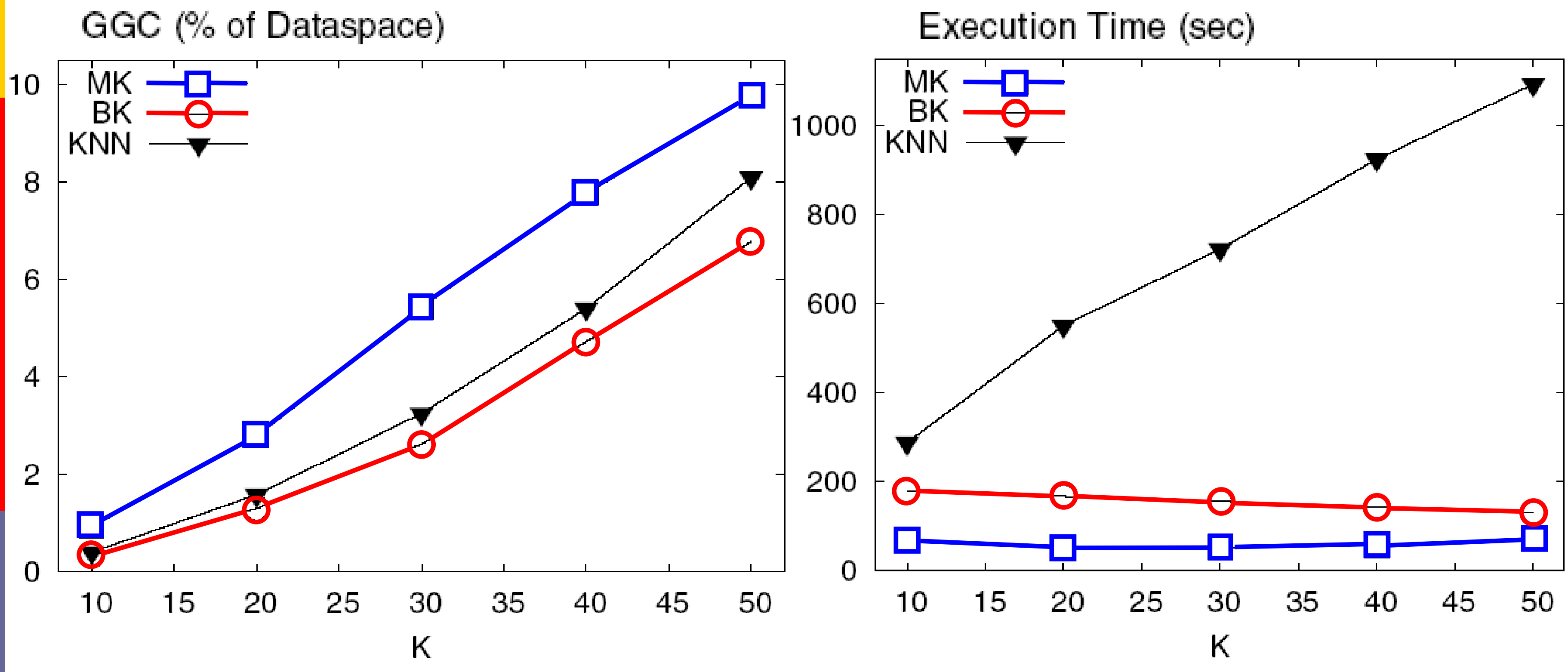
N=10,000 Users

Variable number of sites



N=569,120 Users

Variable *K*



N=569,120 Users

Points to Remember

- Publication of user locations in the proximity of sensitive sites
  - More difficult than Query-privacy in LBS
- “Local” algorithm
  - Very Slow
  - Bad quality, if a secure publishing format is used
- Naïve KNN
  - Also slow
- Our algorithms: MK, BK
  - Fast & Accurate

Bibliography on LBS Privacy

http://anonym.comp.nus.edu.sg