Applications of Moving Objects Databases

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차례

Abstract

- Miniaturization of computing devices and advances in wireless communication and sensor technology
  - Forces propagating computing from the stationary desktop to the mobile outdoors
  - Important classes of new applications
    - Location-based services, tourist services, mobile electronic commerce and digital battlefield
  - Existing application classes
    - Transportation and air traffic control, weather forecasting, emergency response, mobile resource management and mobile workforce

Abstract

- Location management
  - Management of transient location information
    - Enabling technology for all these applications
  - Fundamental component of other technologies
    - Fly-through visualization, context awareness, augmented reality, cellular communication and dynamic resource discovery
- Moving Objects Databases (MODs)
  - Store and manage the location as well as other dynamic information about moving objects

Background

- In 1996, Federal Communications Commission (FCC)
  - Offer a 911 service with the ability to pinpoint the location of callers making emergency requests
    - Roll out costly new infrastructure that provides location data about mobile devices
- In May 2000, the U.S. government
  - Stopped jamming the signals from global positioning system (GPS) satellites
    - Improving the accuracy of GPS-based location data to 5-50 meters
- As prices of basic enabling equipment like smart cell phones, handheld devices, wireless modems and GPS devices continue to drop rapidly
  - The number of wireless subscribers worldwide will soar
  - Companies will roll out new wireless applications(location-based services)

Background

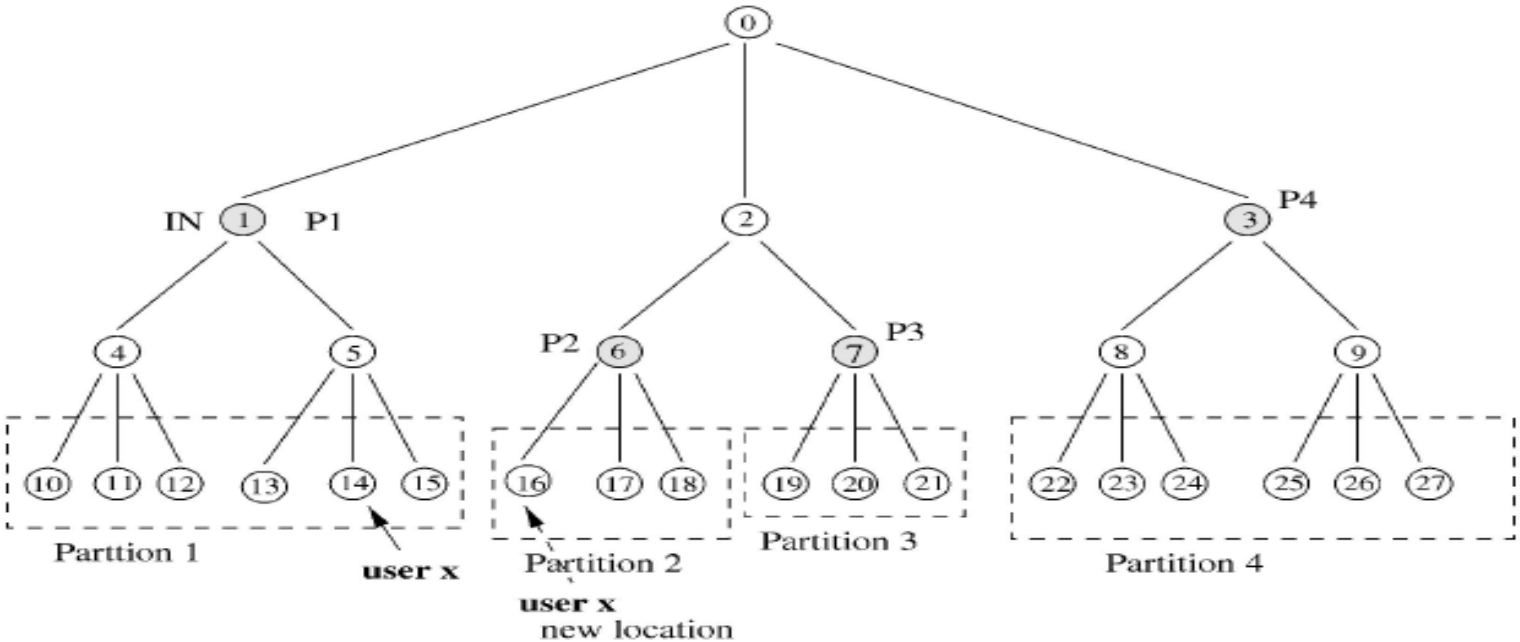
- Emerging commercial location-based services include Mobile Resource Management (MRM) applications
  - Automatic vehicle location, fleet management, logistics, transportation management and support (including air traffic control)
- Another example of location-based service is Location-aware Content Delivery
  - Delivering accurate driving directions, instant coupons to customers nearing a store or nearest resource information like local restaurants, hospitals, ATM machines or gas stations
- In addition to commercial systems
  - Arises in the military in the context of the digital battlefield

Background

- MODs, which include the management of transient location information
  - Enabling technology for all the above applications
  - Fundamental component of other technologies
    - Fly-through visualization, context awareness, augmented reality, cellular communication
- Location management has been studied extensively in the cellular architecture context
  - The problem is as follows
    - The network maintains a database of location records(key, cell-id)
    - Needs to support two types of operations
      - Point query
        - For example, "find the current location (cell) of the moving object with key 707-476-2276"
      - Point update
        - For example, "update the current location (cell) of the moving object with key 707-476-2276"
    - How frequently to update, and how to search the database

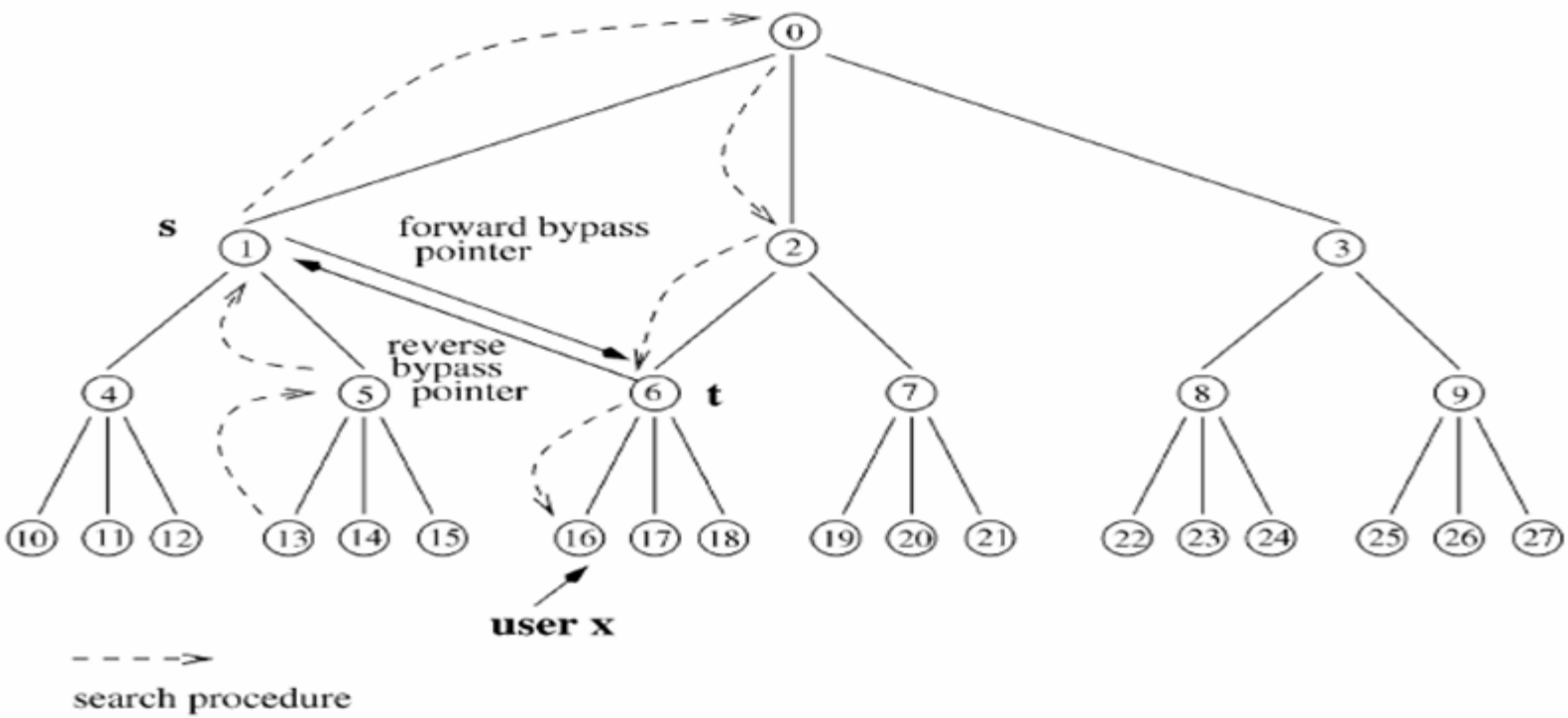
Background

- Pitoura and Samaras(2001)
  - Partitions
    - To avoid maintaining location entries at all levels of the hierarchy, and at the same time reduce the search cost
    - The update cost incurred increases
      - The representatives of its previous and new paritions must be informed



Background

- Pitoura and Samaras(2001)
  - Caching
    - Chahing is based on the premise that, after a call is resolved, the information about the current location of the callee should be reused by any subsequent calls originated from the same region

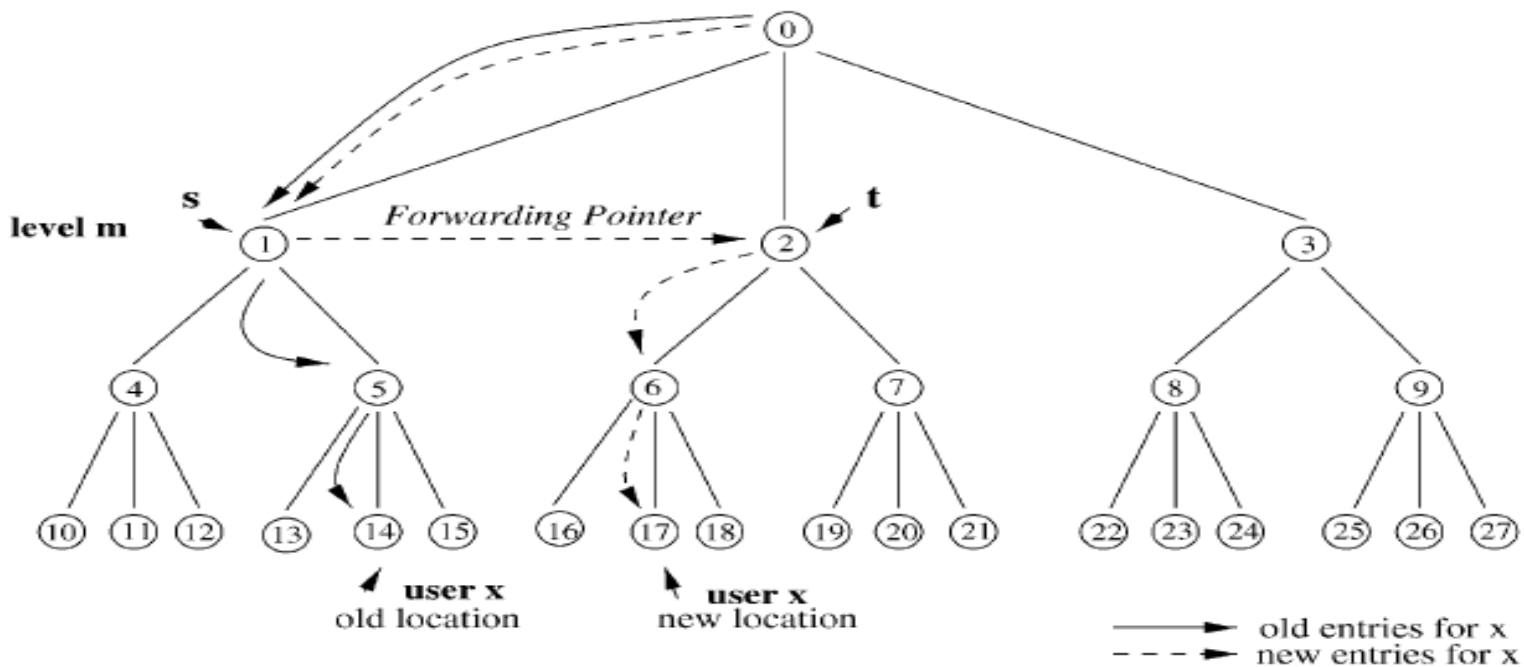


Background

- Pitoura and Samaras(2001)
  - Replication
    - To reduce the lookup cost, the location of specific users may be replicated at selected sites
    - The update cost incurred increases considerably since replicas must be maintained consistent every time the user moves

Background

- Pitoura and Samaras(2001)
  - Forwarding pointers
    - It may be too expensive to update all database entries holding the user's location, each time the user moves
      - Entries may be selectively updated and calls directed to the current location of a user through the deployment of forwarding pointers



Background

- Location management problem addressed by MODs is much broader
  - The main limitations of the cellular work
    - Only relevant operations are point queries and updates that pertain to the current time
    - Only concerned with cell-resolution locations
  - Queries may pertain to the future or the past, and triggers are often more important than queries
    - Examples of queries and triggers supported by MODs
      - Past query
        - "during the past year, how many times was bus #5 late by more than 10 minutes at some station"
      - Set oriented present query
        - "show me the taxi cabs within 1 mile of my location"
      - Future query
        - "retrieve the estimated location of truck #56 tomorrow at 8 a.m."
      - Set oriented future query
        - "retrieve the trucks that will reach their destination within the next 20 minutes"
      - Trigger
        - "send me a message when a helicopter is in a given geographic area"

Background

- In terms of location-based-services software development, the current approach is to build a separate
  - Significant complexity and duplication of efforts
  - Need to develop location management technology
    - Addresses the common requirements
    - Serves as a platform for inventory and personnel application develpment

MOD Applications

- Geographic resource discovery
  - "notify me when I am two miles away from a motel that has rooms available for under $100 per night"
- Digital battlefield
  - "how many friendly tanks are in region X?"
- Transportation(taxi, courier, emergency response, municipal transportation, traffic control, supply chain management, logistics)
  - "which taxi cab is expected to be closest to 320 State Street half an hour from now"
  - "when will the bus arrive at the State and Oak station?"
- Location(or mobile) e-commerce and marketing
  - Coupons and other location-sensitive marketing information are fed to a mobile device

MOD Applications

- Mobile workforce management
  - "which service crew is closest to the emergency at 232 Hill Street?"
- Context-awareness, augmented-reality, fly-through visualization
  - In real time, the relevant information to the current location of a moving user
    - Geologist
- Air traffic control
  - "retrieve the pair of aircraft that are on a collision course"
- Dynamic allocation of bandwidth in cellular network
  - Dynamically change the bandwidth allocation to various cells to satisfy changing customer density
- Querying in mobile environments
  - Knowing the location of the destination computer enables better and more reliable routing of messages
    - Maintaining the trajectories of mobile computers in a MOD is an attractive alternative
      - However, centralized solution defeats the MANET(Mobile Ad-hoc Network) purpose
      - Currently, commercial MOD products provide a very limited set of capabilities

Location Technologies

- Location sensing methods
  - Triangulation
    - GPS
  - Proximity
    - Sensor, RFID tags
  - Scene analysis
    - Analyzing its image produced by a camera

Modeling Based on Point Location Management

- Point location modeling technique
  - Existing industrial applications(fleet management and Automatic Vehicle Location)
    - For each moving object, a location-time point of the form (l, t) is generated periodically
      - l : location(x, y) or cell-id, t : time
      - SQL is used to retrieve the location information
  - Several critical drawbacks
    - The method does not enable interpolation or extrapolation
      - "which police officers were within one mile from the location of an emergency that occurred at 3 p.m."
      - "Which field service employees will be closest to a customer location at 5 p.m"
    - It leads to a critical precision/resource trade-off
      - Bandwidth and processing power
    - It leads to cumbersome and inefficient software development
      - Require the development of a vast array of new software applications

Modeling Based on Point Location Management

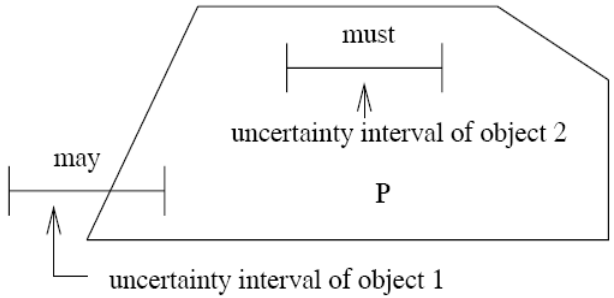
- Point location modeling technique
  - Doing so on top of existing DBMS technology has several drawbacks
    - Not well-equipped to handle continuously changing data
    - Location based services application need to manage space and time information, whereas SQL is not designed and optimized for this type of queries and triggers
    - The location of a moving object is inherently imprecise

Modeling Based on Trajectory Location Management

- Trajectory location modeling technique
  - Databases fOr MovINg Objects (DOMINO's) model of a trajectory
    - Solves the problems associated with point location management
    - If possible, we make use of a priori or inferred information about the destination of an object
      - The destination can be inferred based on a motion pattern or by accessing auxiliary information
    - The method proposed is called trajectory location management
      - Obtain or estimate the source and destination of the moving object
      - By using an electronic map geocoded with distance and travel-time information

Modeling Based on Trajectory Location Management

- Wolfson(1999)
  - Databases fOr MovINg Objects (DONINO's) model
    - MOST(Moving Objects Spatio-Temporal)
      - Dynamic attributes
        - DBMS knows the speed and the route of a moving object
        - Compute its location at any point in time without additional updates
    - FTL(Future Temporal Logic)
      - Spatial and temporal query language
        - It is basically SQL augmented with temporal operators(e.g. SOMETIME-DURING, UNTIL, LATE) and spatial operators(e.g. INSIDE-REGION)
    - Uncertainty/imprecision management
      - FTL language is extended
      - Two kinds of semantics(may and must)



Modeling Based on Trajectory Location Management

- Trajectory location modeling technique
  - Electronic Maps
    - A city block
      - Polyline : the block polyline given by a sequence of 2D x, y coordinates
      - Fid : the block id number
    - Attributes are used for geocoding
      - L_f_add : Left-side-from street number
      - L_t_add : Left-side-to street number
      - R_f_add : Right-side-from street number
      - R_t_add : Right-side-to street number
      - Name : street name
      - Type : ST or AVE
      - Zipl : Left side Zip code
      - Zipr : Right side Zip code
      - Speed : speed limit on this city block
      - One way : a Boolean One way flag
    - Attributes are used for computing travel time and travel distance
      - Meters : Length of the block in meters
      - Drive time : Typical drive time from the one end of the block to the other, in minutes

Modeling Based on Trajectory Location Management

- Trajectory location modeling technique
  - Dealing with Trajectories
    - An external routine available in most existing Geographic Information Systems
    - Computes the shortest cost path in the map graph
      - O : moving object
      - This path denoted P(O) is given as a sequence of blocks
      - The whole route represented by P(O) is a polyline denoted L(O)
    - C-trajectory(Certain-trajectory)
      - Sequence of straight-line segments(x_1, y_1, t_1), (x_2, y_2, t_2), … , (x_n, y_n, t_n) in 3-dimensional space
      - The number of line segments on the trajectory
        - Important implication on the performance and precision of queries and triggers

Modeling Based on Trajectory Location Management

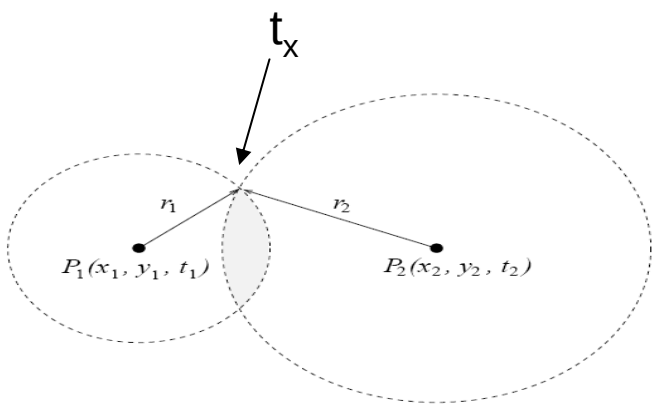
- Trajectory location modeling technique
  - Dealing with Trajectories
    - C-trajectory
      - Solves the first problem associated with point location management
        - Compute the expected location of the moving object at any point in time between the start and end times of the trip
      - Solves the second problem of point location management
        - The trajectory is obtained by associating an uncertainty threshold u_i with the ith line segment on the c-trajectory
        - The moving object will update the server if and only if it deviates from its expected location according to the trajectory by u_i or more
        - Polyline $(x_1, y_1, t_1, u_1), (x_2, y_2, t_2, u_2), \ldots, (x_n, y_n, t_n, u_n)$
        - Location of a moving object can be computed with a high degree of precision using a small number of location updates or no updates at all
      - According to real-time traffic conditions obtained from traffic Web sites

Modeling Based on Trajectory Location Management

- Pfoser & jensen(2000)
  - Measurement error
    - Error in a positional GPS measurement
  - Uncertainty in sampling
    - Uncertainty about the position of the object in-between the measurements
    - v_m = object's maximum speed

$r_1 = v_m(t_x - t_1)$

$r_2 = v_m(t_2 - t_x)$



MOD Architecture and Functionality

- A MOD consists of static geo-spatial and temporal information, some of which is updated in real time
  - The static information includes maps, profile information about moving objects and motion plans
  - The real time updates include current location and other information fed in by sensors

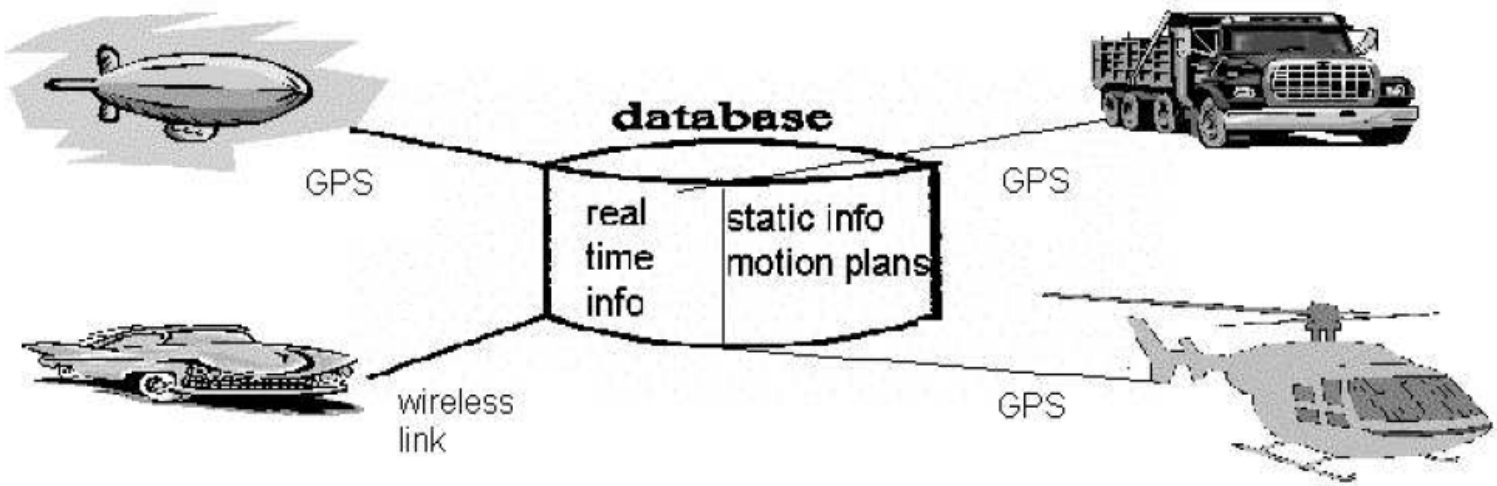
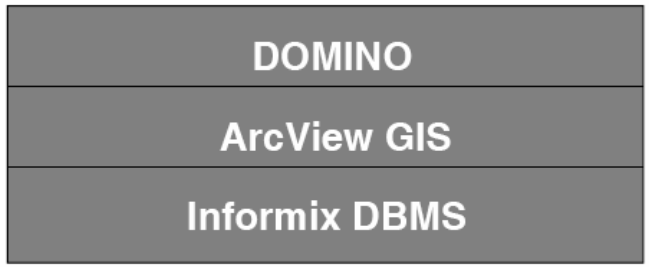


Figure 1: Moving Objects Database technology

MOD Architecture and Functionality

- MOD Architecture
  - A MOD stores and manages the location as well as other dynamic information about moving objects
    - Three-layer architecture
      - A software envelope that manages the dynamic aspects of the system
      - A geographic information system (GIS) that provides different functionalities to deal with geo-spatial information
      - A DBMS that actually stores and manages the data



  - Centralized architecture
    - Distributed approach to deal with location queries that involve moving objects highly distributed geographically

MOD Architecture and Functionality

- Milojisic et al(1998)
  - MASIF(Mobile Agent System Interoperability Facility)
    - Standard for mobile agent systems which has been adopted as an OMG(Object Management Group) technology
  - Functions of an Agent System
    - Transferring an agent,
    - Creating an agent
    - Providing globally unique agent names and locations
    - Finding a mobile agent
    - Ensuring a secure environment for agent operations

MOD Architecture and Functionality

- MOD Functionality
  - Demonstrate the query language and user interface for the DOMINO system
    - "Where are the vehicles at 12:35 ?"

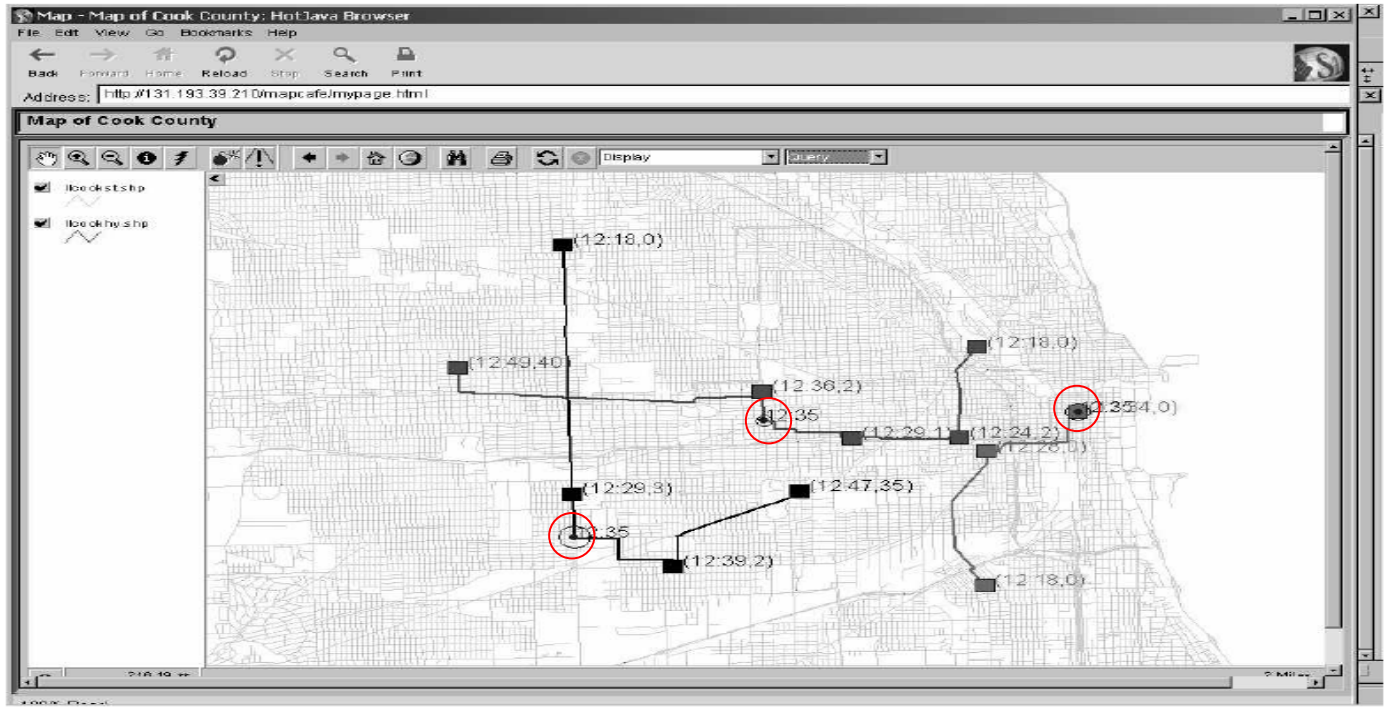


Figure 2: Query result showing all vehicles' locations at 12:35

MOD Architecture and Functionality

❖ MOD Functionality

◆ "Which moving object is closest to the star between 12:35 and 12:50 ?"

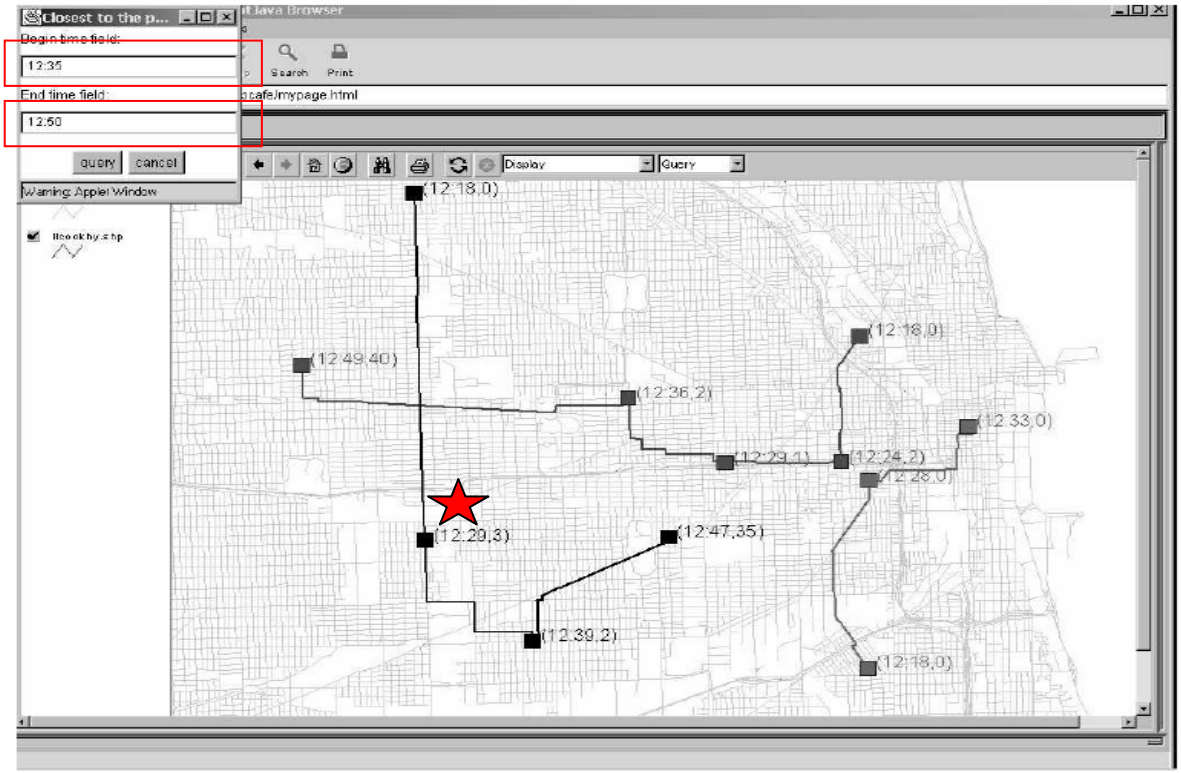


Figure 3: Which vehicle will be closest to the "star" between 12:35 and 12:50?

MOD Architecture and Functionality

❖ MOD Functionality

◆ The answer of the query (Figure 3)

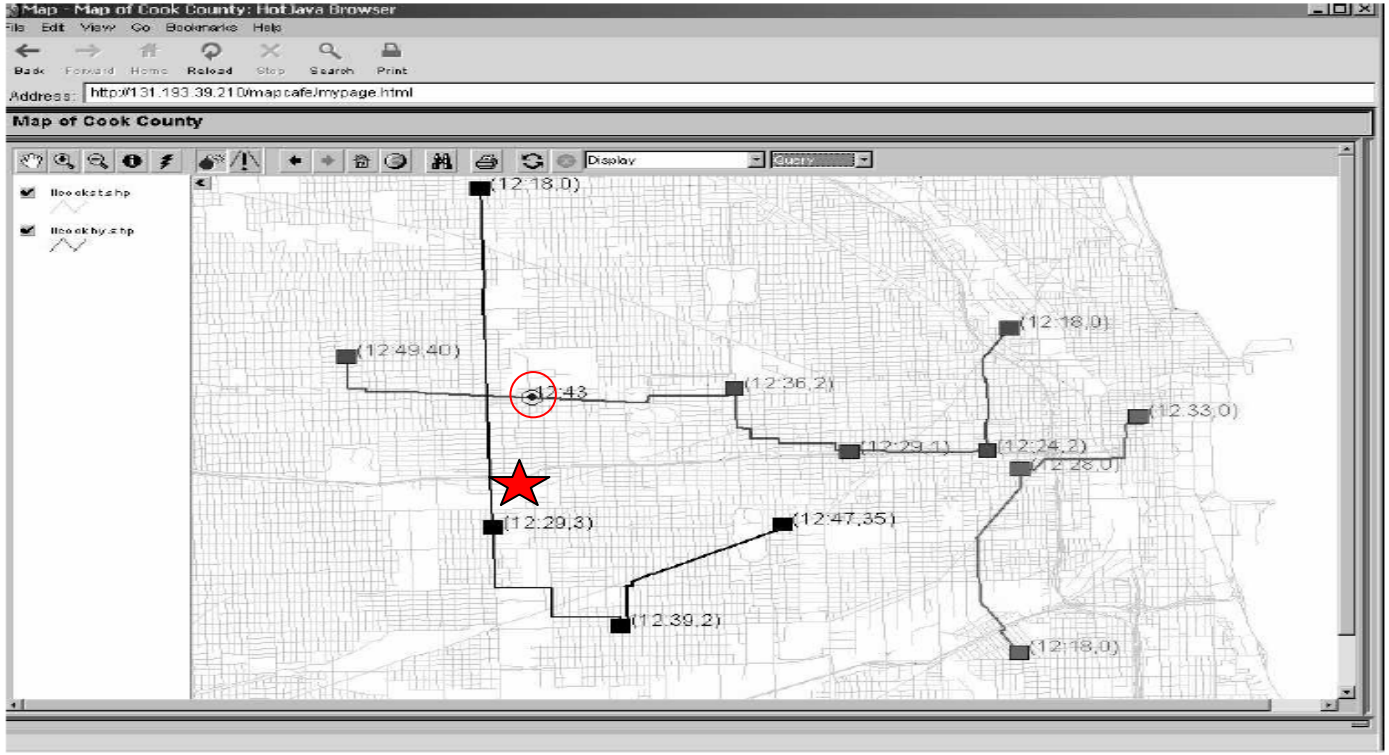


Figure 4: Answer: The vehicle (see the circle) on the red route

MOD Architecture and Functionality

- MOD Functionality
  - Another sample location query

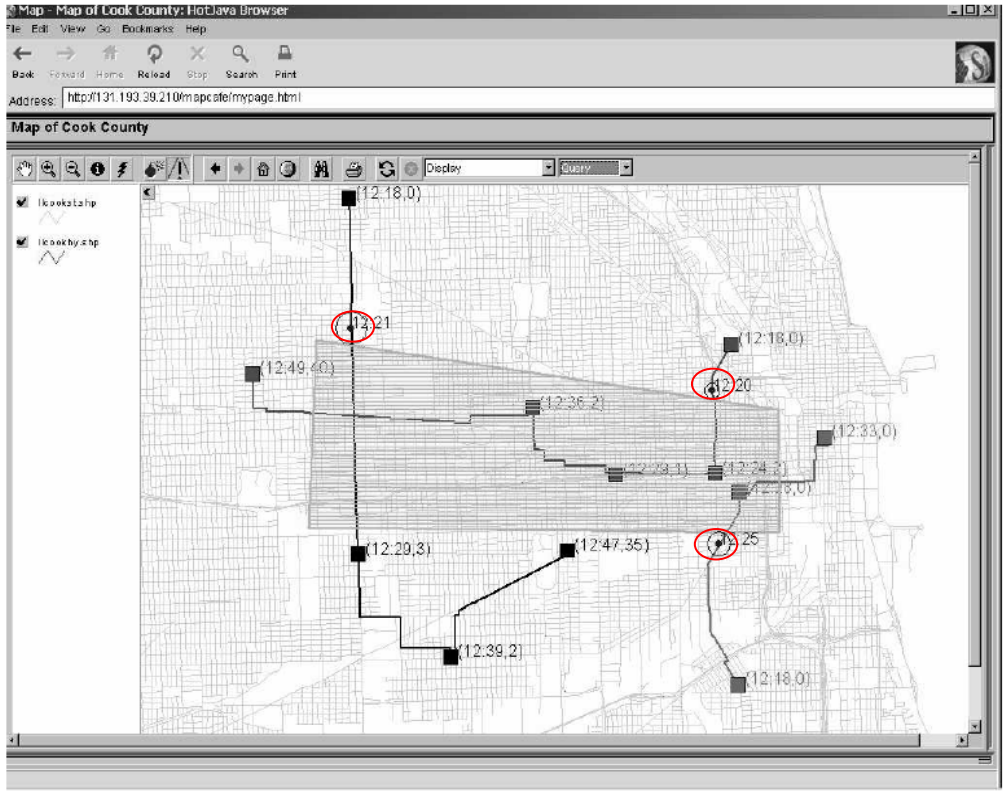


Figure 5: When will each vehicle enter the specified sector? (shown as shaded area)

Conclusions

- Focused on location management
  - Technology for a variety of applications and technologies related to this revolution
- The research issues
  - Location modeling
    - Drawbacks of existing approaches
    - Proposed the trajectory as a four-dimensional
- MOD architecture and functionality
  - Pointing out the need for considering a distributed approach for the location query processing
  - Demonstrated the query language and user interface for the DOMINO system

Future Trends

- MODs will become increasingly important and that DBMS' should be made the platform for developing moving objects applications
  - Spatio-temporal query languages
  - Support for rapidly changing real-time data
  - Indexing
  - Distributed/mobile query and trigger processing with incomplete/imprecise location information
- More specific open issues
  - Extend the present work to handle uncertainty for moving objects
  - Data mining techniques can be used to extract interesting information (for instance, trajectories of moving objects) from location data
  - Extensible and visual languages should be defined
  - Distributed approaches must be developed to process location queries in order to fit the natural distribution of mobile scenarios