Local Positioning Techniques with Emphasis on Bluetooth

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Sources of Presentation

1) J. Caffery, *Wireless Location in CDMA Cellular Radio Systems – Chapter 2 &3* , Kluwer Academic Press, 1999.

2) B. Miller and C. Bisdikian, *Bluetooth Revealed*, Prentice-Hall, 2001.

3) Bluetooth Special Interest Group, *Bluetooth V1.1 Core Specifications*, available from http://www.bluetooth.com , February 2001.

4) Bluetooth Special Interest Group, *Bluetooth V1.1 Profile Specifications*, available from http://www.bluetooth.com , February 2001.

5) T. Siep, *An IEEE Guide: How to Find What You need in the Bluetooth Spec*, IEEE Press, 2001.

6) A. Cole, Local Positioning Profile, *Bluetooth Doc*, available from http://www.bluetooth.org, June 2001.

7) M. Overy, Bluetooth Local Positioning Market Requirements Document, *Bluetooth Doc*, available from http://www.bluetooth.org, May 2001.

Definitions

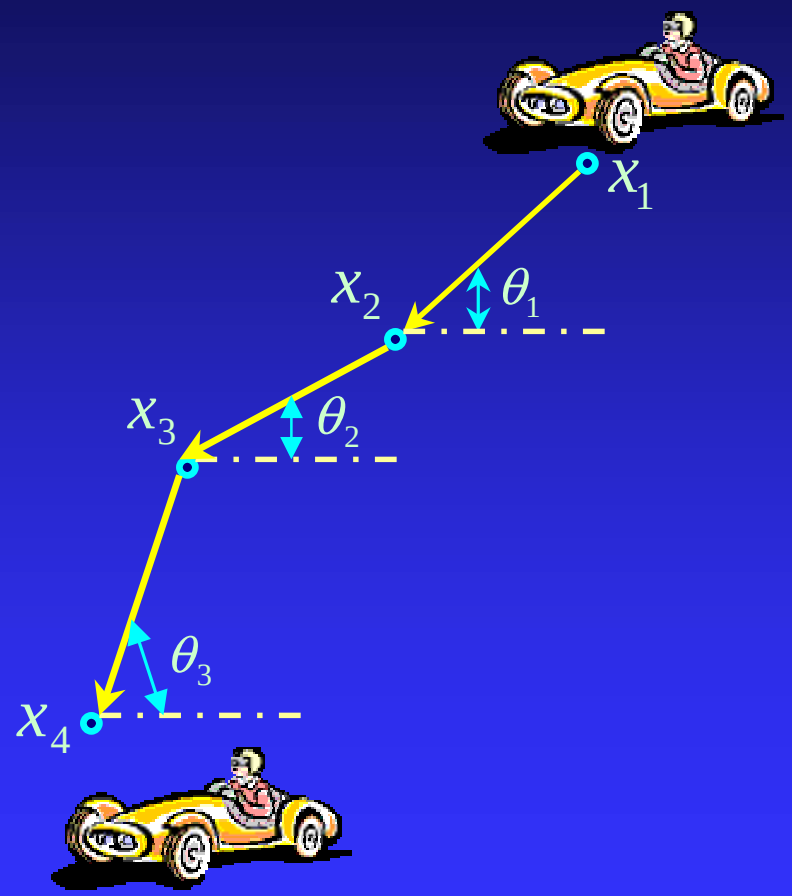
- *Position* refers to a numeric description within a coordinate system.
- *Location* refers to information about surrounding objects and their inter-relationships.
- *Local Positioning* is used to determine the position of devices.
- Devices at unknown positions can *estimate their positions* by proximity to devices with known positions.
- Bluetooth has the potential to offer Local Positioning at *minimal cost* and with *maximum geographic coverage*.

Location Methods

- Have been an active field of study over the last few decades.
- Originally, for the purpose of monitoring vehicles from law enforcement agencies, taxi fleet operations, emergency medical services.
- Recently, for the purpose of wireless system design, determining cell service area, traffic monitoring in mobile cellular radio.
- Generally divided into three categories:
  - *Dead-Reckoning*
  - *Proximity systems*
  - *Radiolocation*

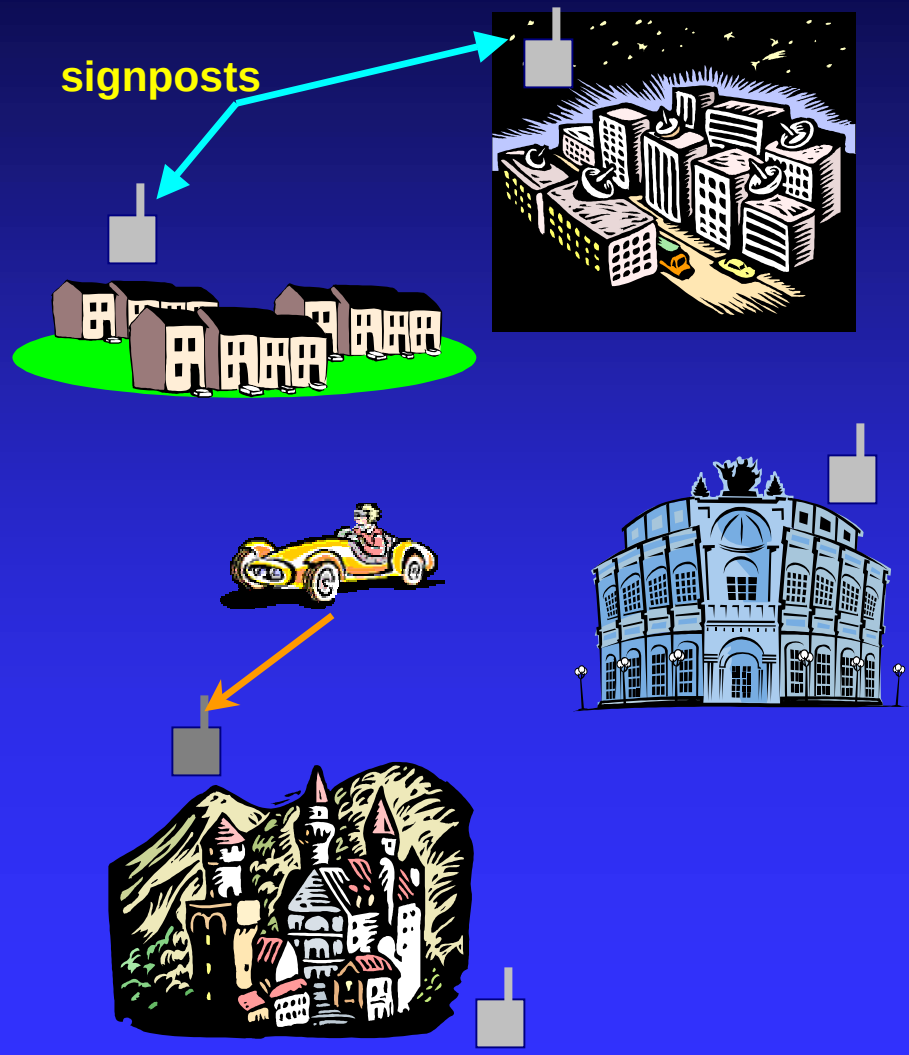
Dead-Reckoning

- Based on the concept of the *direction* and the *distance* from a starting point.
  - *Starting Position*
    $$X_0 = [x_0, y_0]$$
  - *Displacement Vector*
    $$D_i = [d_i \cos\theta_i, d_i \sin\theta_i]$$
  - *Location*
    $$X_n = X_0 + \sum_{i=0}^{n-1} D_i$$
- Depends on the previous estimates and many factors lead to position errors.



Proximity Systems

- The nearness of the MS to the proximity *detectors or signposts* (BS) gives an indication of the location of MS.
- The *BS antennas would replace the specialized detectors* to provide a wide area of coverage for proximity detection.
- The usefulness of this approach and its general accuracy depends on the *size of the cells*.



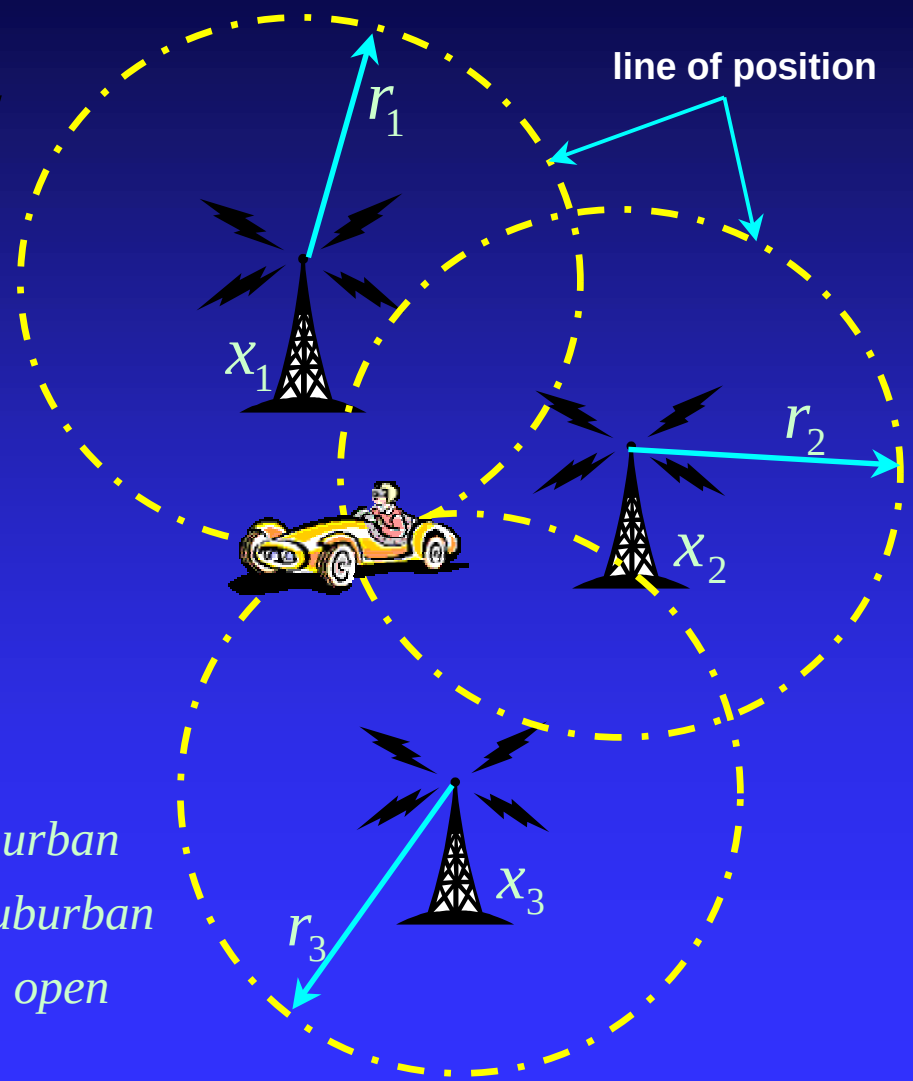
Radiolocation Systems

- Locate a MS by *measuring the radio signals* traveling between the MS and a set of BSs.
- *Self-Positioning/Forward Link:* MS formulates its own position from signal received from the BS.
- *Remote-Positioning/Reverse Link:* the position of the MS can be calculated at a remote location based on the signal received at the BS.
- Three main techniques:
  - *Signal Strength*
  - *Angle of Arrival (AoA)*
  - *Time-Based (ToA or TDoA)*

Signal Strength

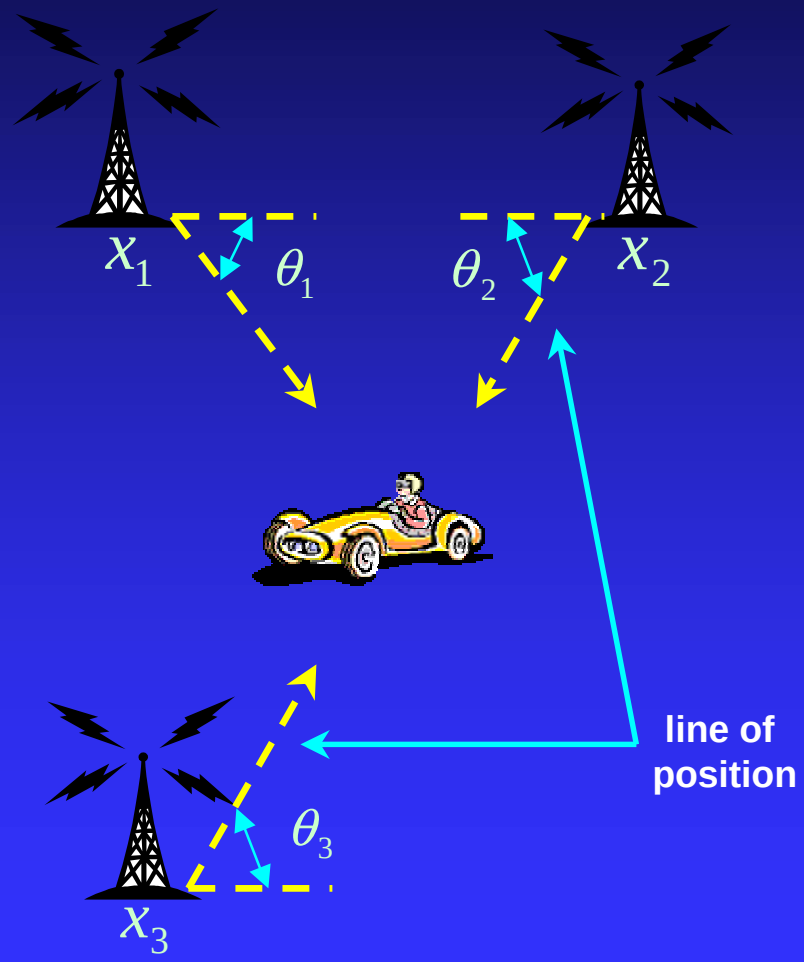
- *Path loss* predicates how the signal power decays with distance from a BS.
- The primary source of error is *multipath fading* and *shadowing*.
- Hata's Model in macrocells based
  - *BS height*
  - *MS height*
  - *Carrier Frequency*
  - *Type of Environment*

$$L_p(d) = \begin{cases} A + B\log_{10}(d) & urban \\ A + B\log_{10}(d) - C & suburban \\ A + B\log_{10}(d) - D & open \end{cases}$$



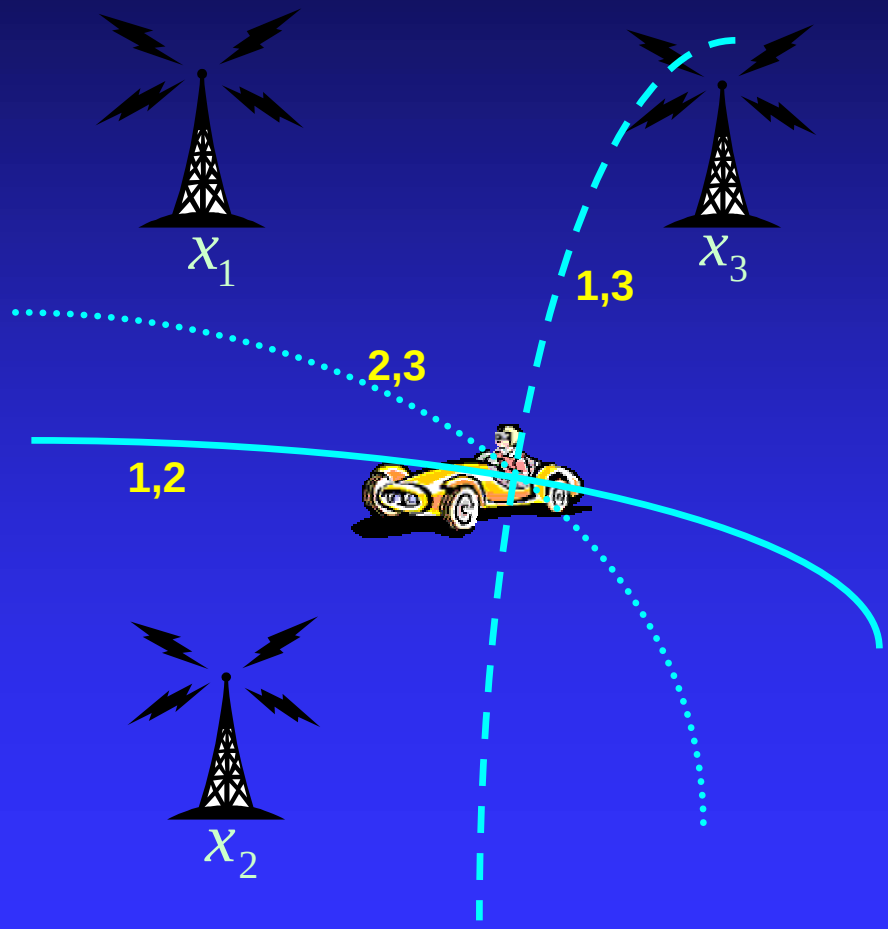
Angel of Arrival

- Estimate the MS location by *measuring the arrival angle* of a signal from a MS at several BSs through the use of directive antennas.
- The *lines of position* are straight lines whose intersection provides the location of the MS.
- The accuracy of AOA diminishes with increasing distance between MS and BS due to the *scattering environment*.



Time-Based Methods

- Estimate the *ToAs* of a signal transmitted by MS and received at multiple BSs.
- Estimate the *TDoAs* of a signal received at multiple pairs of BSs.
- The lines of position are hyperbolas whose intersection provide the location of MS.
- The accuracy does not degrade with increasing MS-BS distances.



Pros and Cons of Location Methods

- Dead-Reckoning
  - *Does not require a large infrastructure of devices to locate a MS.*
  - *Relies on specialized equipment for self-positioning of a MS.*
- Proximity Systems
  - *Sectors of cells may be used for proximity detection.*
  - *Enables coarse positioning but suffers the disadvantage of large infrastructure costs to outfit an area with sensors.*
- Radiolocation
  - *Finds a natural fit in wireless communications systems.*
  - *Has the remote-positioning as a choice based on the pre-existing infrastructure of transmitters and receivers.*
  - *Has the self-positioning as a possibility requires the MS handset have "built-in" location technology.*

Bluetooth History

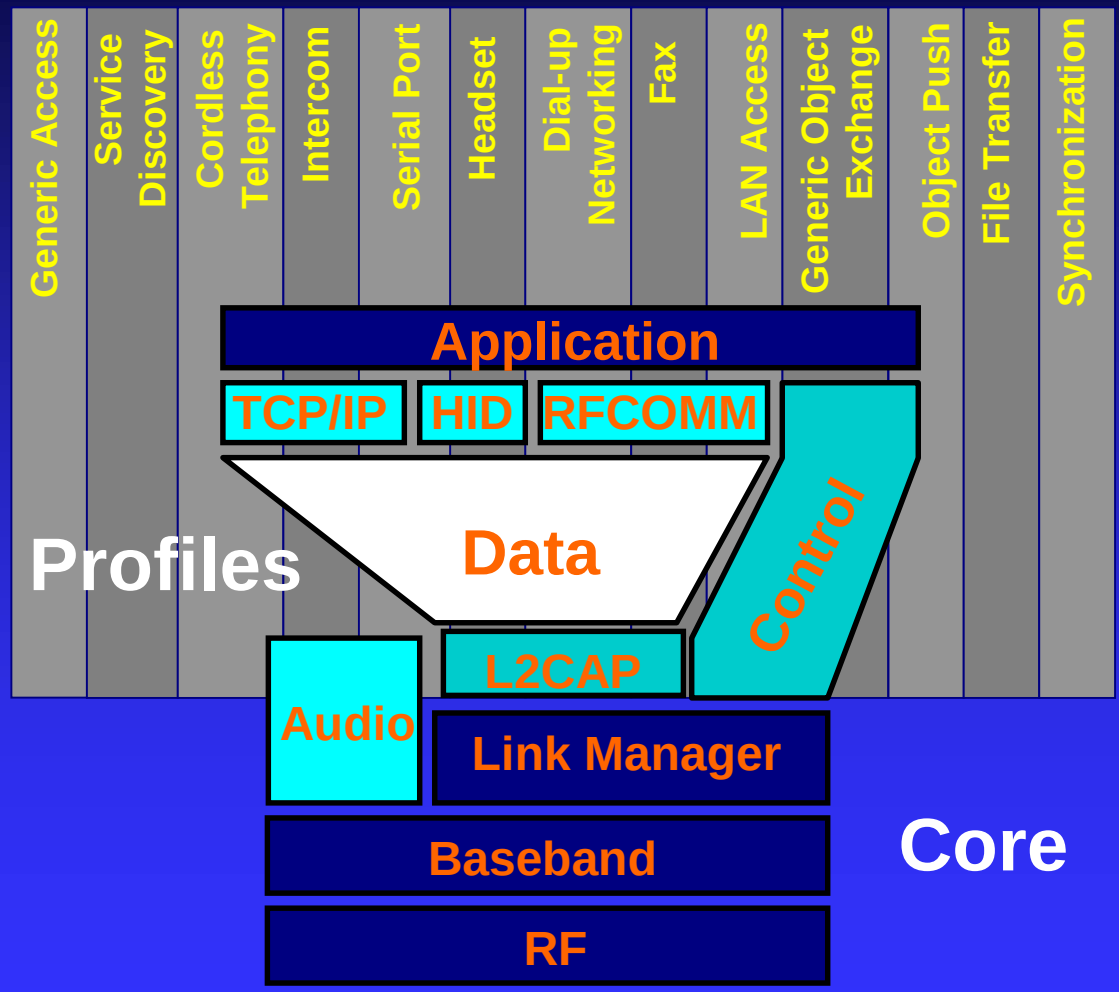
- An *open specification* for a technology to enable short-range wireless voice and data communications anywhere in the world.
  - In 1994, Ericsson begun a project to study the feasibility of a low-power and low-cost radio interface to eliminate cables between mobile phones and their accessories.
  - In May 1998, *Promoter Companies* (Ericsson, Intel, IBM, Nokia, Toshiba) formed *Bluetooth Special Interest Group* (SIG) to produce an open specification.
  - In December 1999, four new promoter companies (3Com, Agere, Microsoft, Motorola) joined the SIG, and 2500 *Adaptor Companies* and *Associate Members*.

Bluetooth Name

- Herald Blatand
  - king of Denmark 940-984
  - united Denmark and Norway
  - brought Christianity to Scandinavia
- Blatand → Bluetooth
  - its origin in Scandinavia
  - intended to unify multinational companies
  - established a new transcultural mode of communication

Public Bluetooth Specification

- *Core* gives a picture of the technology in traditional layer approach, starting at the radio as the foundation and working upward (Parts A-I).
- *Profiles* take a vertical slice of the technology for each of several applications (Part K).



From Reference [5] – Page 5

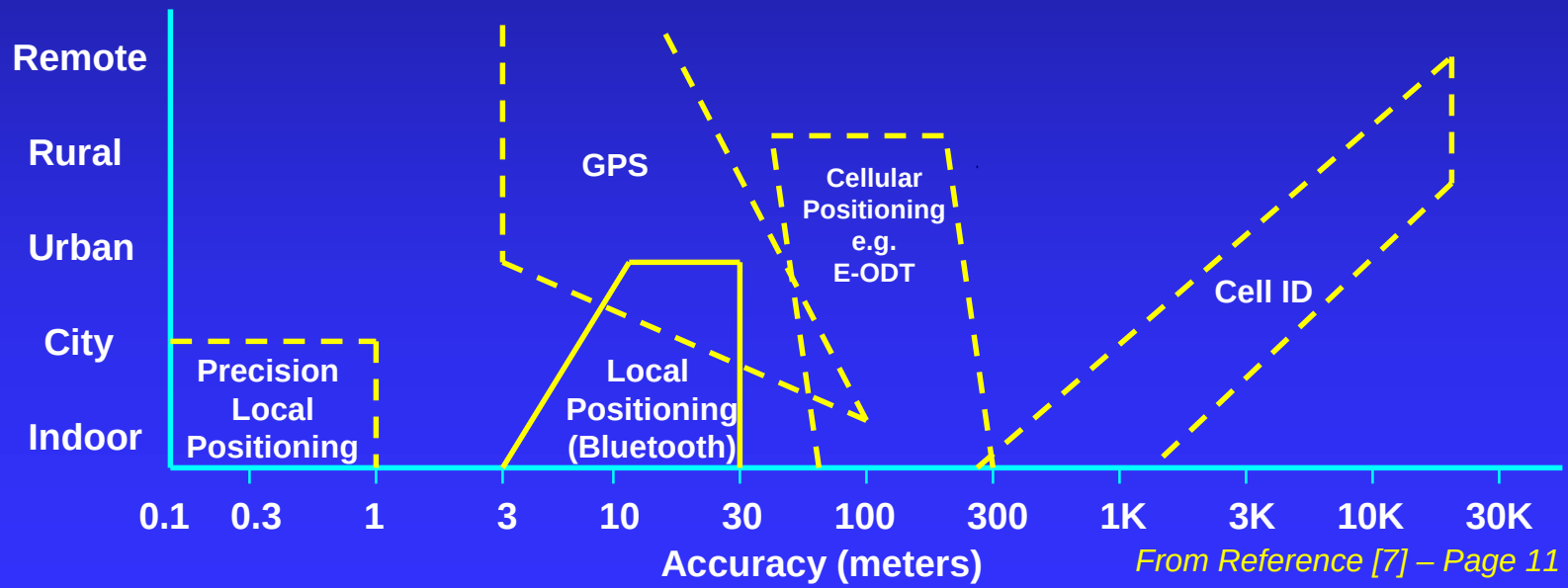
Bluetooth SIG Working Groups

- *Working groups* focus on a specific part of the technology or on some supporting service.

- Specification Drafts / Profiles exist for the following working groups:
  - Audio Video (AV)
  - CAR
  - Extended Service Discovery Profile (ESDP)
  - Human Interface Device (HID)
  - Imaging
  - Integrated Services Digital Networks (ISDN)
  - Local Positioning (LP)
  - Personal Area Network (PAN)
  - Printing

Wireless Positioning Technology

- A trade-off between *range* and accuracy.
  - *Microwave systems*: highest accuracy (1m), but operates in line-of-sight.
  - *Ultra-high frequency*: high accuracy (a few tens of meter), but ranges up to 400km.
  - *Low-frequency*: greater range, but reduced accuracy (50m).
  - *Very-low-frequency*: greatest range (several thousand kilometers), but very poor accuracy (kilometers).



From Reference [7] – Page 11

BT Local Positioning Profile - Scope

- Defines the protocols and procedures that will be used by Bluetooth devices implementing:
  - Position Determination
    - *Target is provide GPS like accuracy (3-30m outdoors), especially for indoor environments.*
  - Location Awareness
    - *Picking up local contextual information.*
    - *Picking up local URLs.*
    - *Time synchronization*

BT Local Positioning - Applications

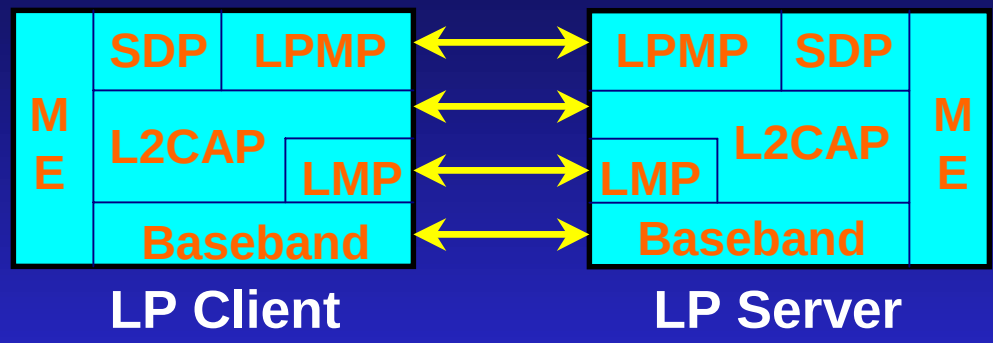
- Class1
  - For devices with no other positioning capability (e.g., laptops).
- Class 2
  - For devices with GPS and or cellular positioning capability (e.g., cell phones), to improve performance indoors and in built up locations.
- The market for location based services is forecast to be huge (estimates > $30b in 2005).

BT Local Positioning - Objectives

- General Objectives
  - Exchange of Local Positioning Information
  - Maintaining a Device's Right to Privacy
  - Quality of Service
- Technology Objectives
  - Compatibility with Other Positioning Technologies
  - Local Positioning Accuracy and Reliability
  - Battery Life
- Implementation Objectives
  - Minimize Impact to Devices Used in Local Positioning
  - Local Positioning May be Disabled by the Device User

Bluetooth LP Profile Stack

- Local Positioning Message Protocol (LPMP) uses the connection-oriented transport service in L2CAP which uses the Baseband ACL links to carry LP messages.
- Discovery of LP services is performed by SDP after establishing an L2CAP connection.
- Management Entity co-ordinates procedures during initialization, configuration, connection management.



- LP Client provides the ability to locate a LP server and use the LP Messaging Protocol to request LP data.
- LP Server provides the ability to respond to requests for positioning data via the LP Messaging Protocol.

Features Provided by LP

	Feature	*Support in Client*	*Support in Server*
Step 1	Locate and Select LP Server	M	O
Step 2	Simple Data Pull	M	O
	Request Position Fix	O	O
	Perform Position Fix	N/A	O
	Send Response Message	N/A	M

M: Mandatory for support

O: Optional for support

The First Step

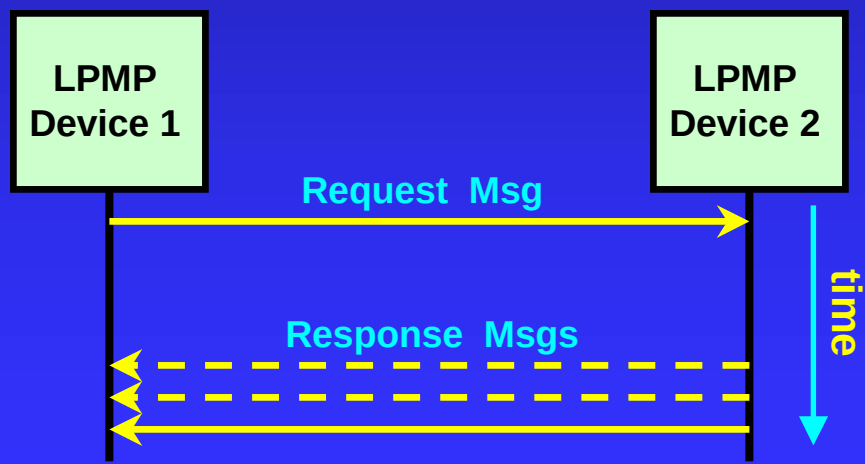
- The client must *attempt to locate LP Server* devices within communication range.
- The client *performs an inquiry period* and *collects the consequent FHS packets* from neighboring devices.
- The SDP protocol is used to *locate dedicated LP Servers* by performing an SDP query.
- After selecting a server, the client *establishes an ACL connection* between the devices.
- *LP authentication schema* is based on the LMP authentication used by GAP.

The Second Step

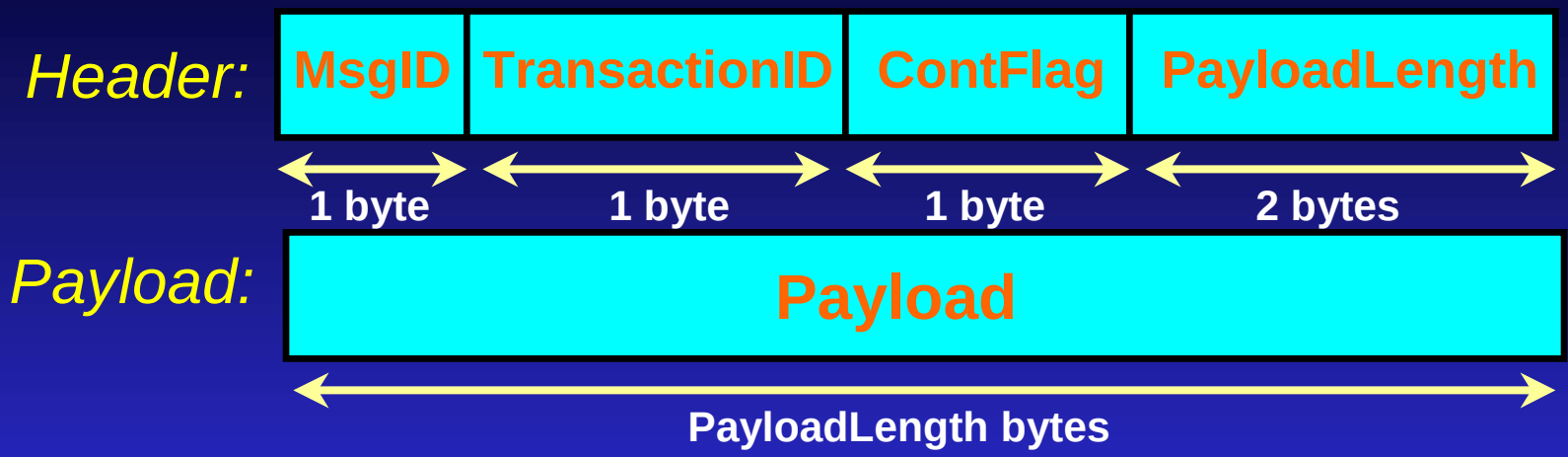
- The client initiates each LP transaction using:
  - LPMP Request Messages
    - LP_PositionRequest
    - LP_PositionFixRequest
- Upon receipt of an LP request message, the server sends one or more response messages:
  - LPMP Response Messages
    - LP_Error
    - LP_Status
    - LP_PositionResponse

LPMP Description

- LPMP transfers multiple-byte fields with MSB being transferred before LSB.
- Messages consist of one or more associated Protocol Data Units (PDUs) sent from one device to another.
- It is up to the implementation to be tolerant of missing packets from L2CAP.



Protocol Data Unit (PDU) Format



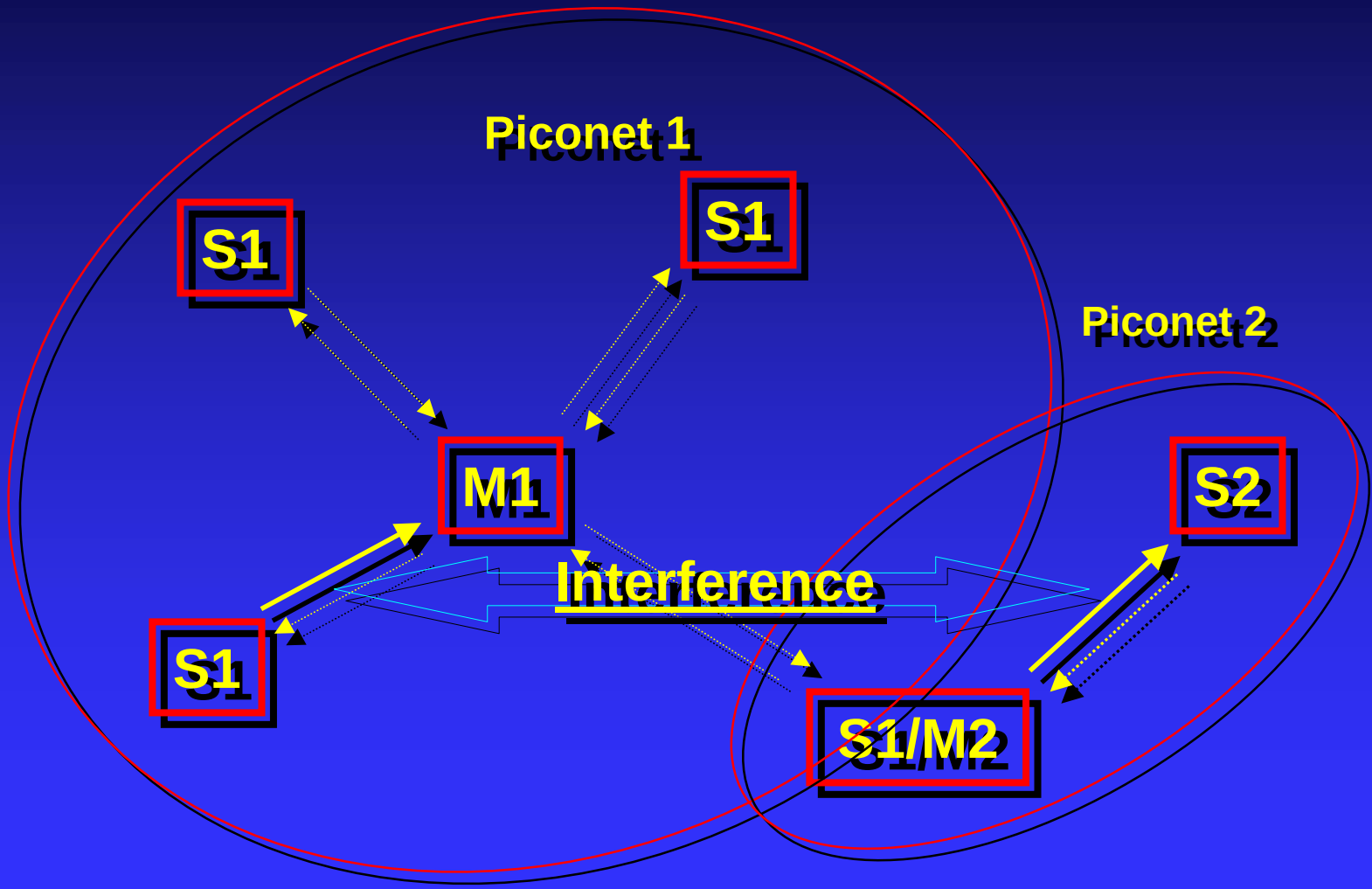
MsgID	*Name*	*MsgID*	*Name*
0x00	Reserved	Response Msgs (0x80 - 0xFF)	
Request Msgs (0x01- 0x07)		0x80	LP_Error
0x01	LP_PositionRequest	0x81	LP_Status
0x02	LP_PositionFixRequest	0x82	LP_PositionRequest
0x03 - 0x07	Unassigned	0x83 - 0xFF	Unassigned

Local Positioning Data Format

- Defines the formats for the exchange of numeric Local Positioning using the LPMP mechanism.

Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1
TIME _INCL	STATUS _INCL	VELOCITY _INCL	DISTANCE _INCL	ALTITUDE _INCL	V_SPEED _INCL	VEHICLE _STATUS	ELAPSED_ TIME_INCL
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	TEXT_INCL	URL_INCL
(MSB) Shape (LSB)				(MSB) Number of Points (LSB)			
Mobility		Fix Type		(MSB) ERP (LSB)			
Reserved	(Sign)	(MSB) Latitude					
Latitude (continue)							
Latitude (continue)							
Latitude (continue) (LSB)							
(MSB) Longitude							
Longitude (continue)							
Longitude (continue)							
Longitude (continue) (LSB)							
Reserved	(MSB) Confidence (LSB)						
(MSB) Uncertainty 1 (r1 or zero) (LSB)							
(MSB) Uncertainty 2 (r2 or r) (LSB)							
(MSB) Orientation / Angel (LSB)							

Power Control in Bluetooth



Conclusion

- Bluetooth Local Positioning is targeting to *maximize the value of Location* with *minimum cost*.
- Potential to provide *GPS like accuracy indoors*, virtually for free, plus local contextual information.
- As GPS and Bluetooth become widely used, *most wireless devices will include positioning capability*.

Question & Answer