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Exploring Potential Human Activities in Physical and Virtual Spaces: A Spatio-temporal GIS Approach

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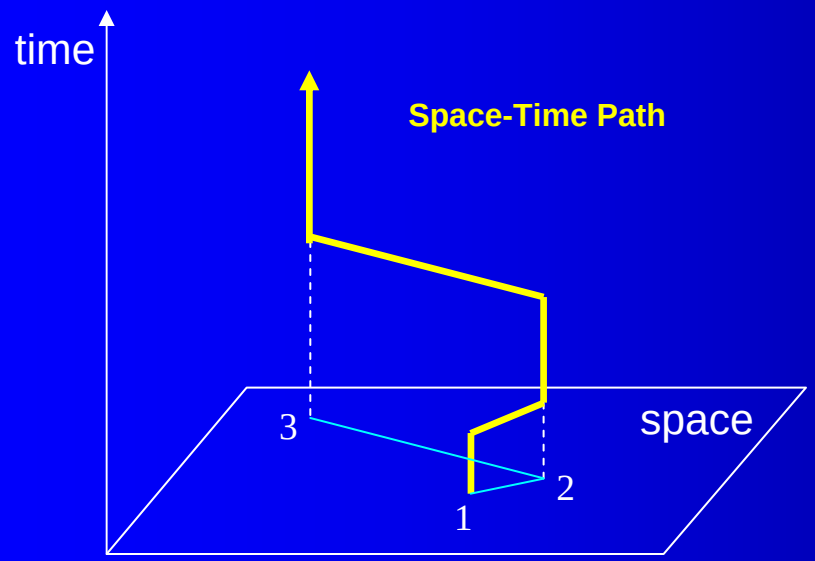
Introduction

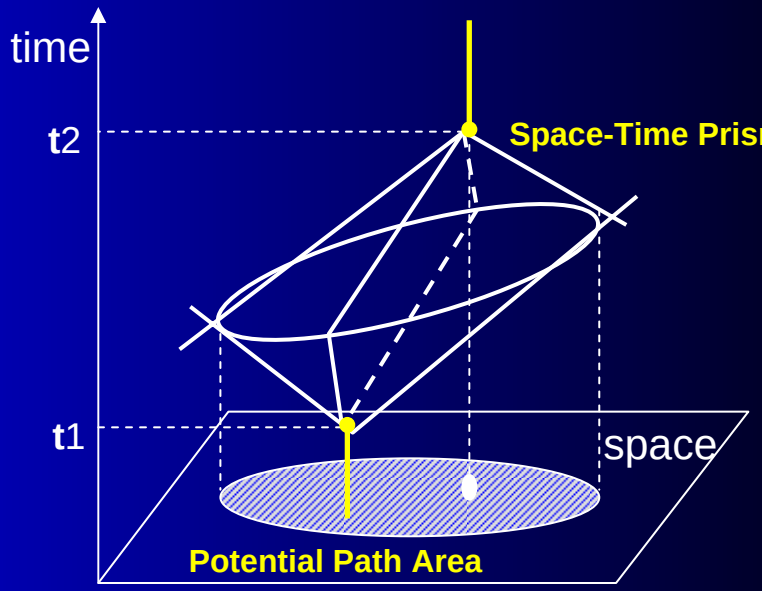
- Physical presence vs. tele-presence
  - *Information and communication technologies* (ICT) have enabled a virtual space.
  - People can participate in activities and interact with others *remotely* through *tele-presence* instead of *physical presence*.
- Time geography (Hägerstrand, 1970)
  - It provides a useful framework to study spatial and temporal aspects of individuals' activities.
  - Activities in the virtual space are not well addressed.
  - Limited progress is made to develop a GIS-based operational system.
- The main objective of this research is to develop an operational time-geographic GIS for representation, analysis, and visualization of human activities in physical and virtual spaces.

Time Geography

- Hägerstrand (1970) proposed a framework to study the relationships between various constraints and human activities in a space-time context.

- Three key concepts: space-time path (ST path)
  space-time prism (ST prism)
  potential path area (PPA)

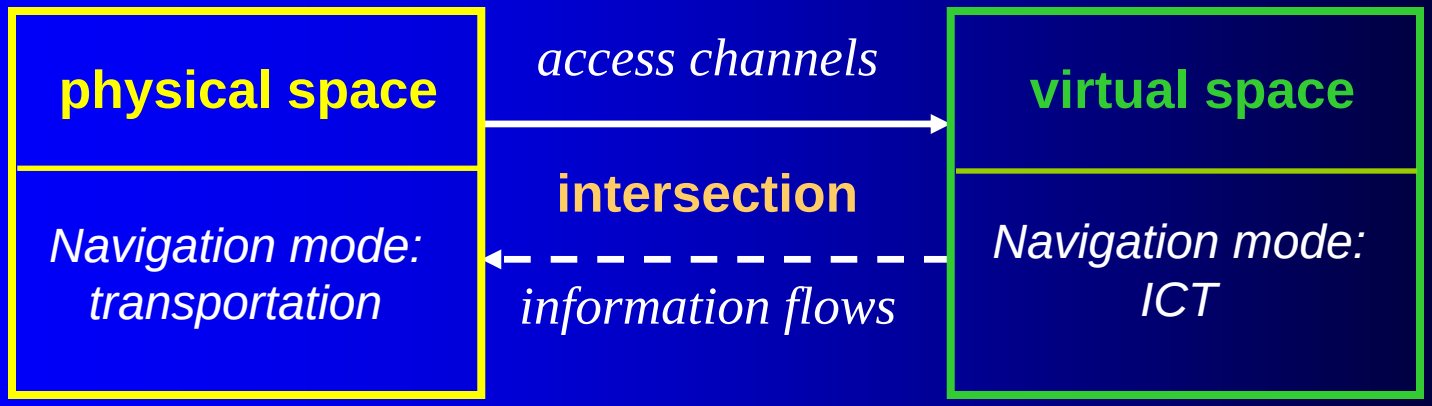




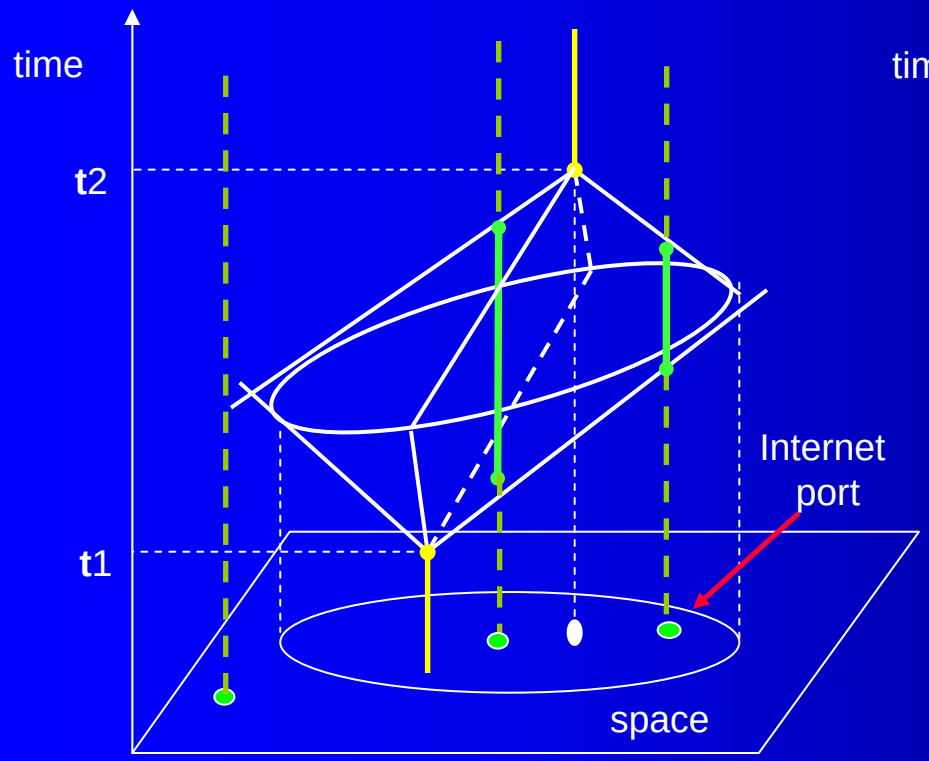
A Conceptual Model for Physical and Virtual Spaces

- Physical space and virtual space have different rules to control activities within their domains.

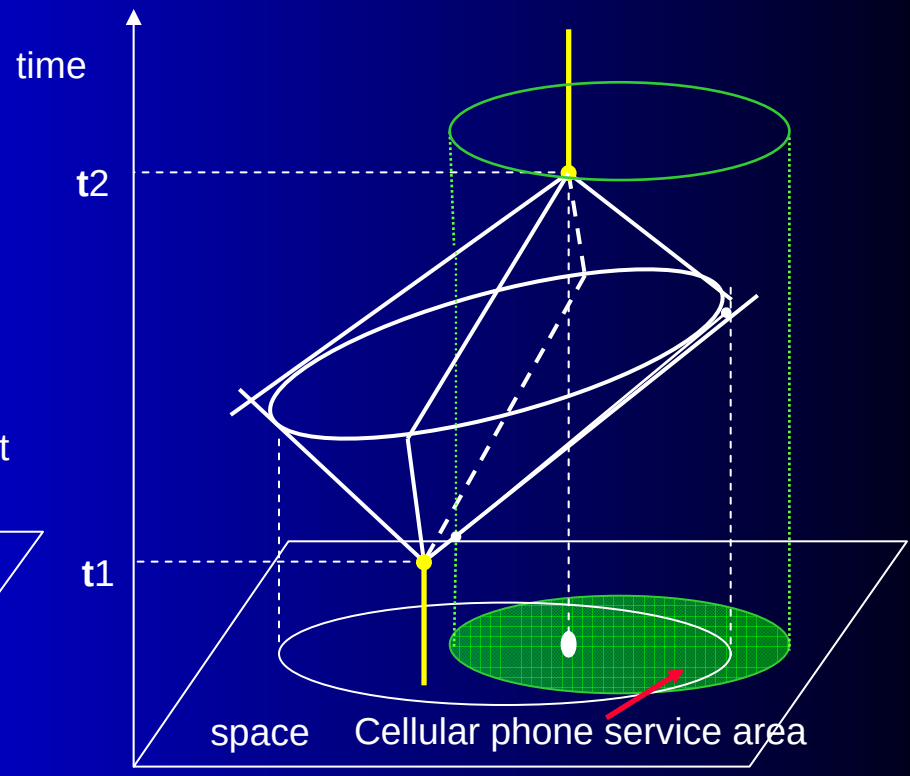
- In the meantime, the two spaces also intersect with each other.
  - The physical space provides *access channels* to the virtual space.
  - The virtual space feeds back *information* to impact individuals' activities and travel patterns in the physical space.



Space-time Prisms for Virtual Activities



ST Prism for wired access



ST Prism for wireless access

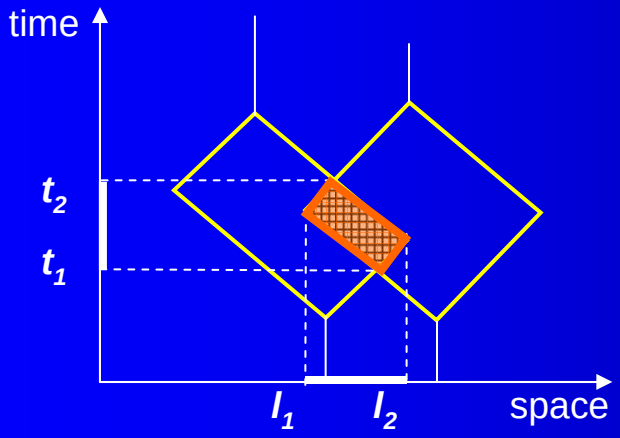
Four Types of Communication Modes

- Four types of communication modes have been identified based on their spatial and temporal characteristics (Janelle, 1995; Harvey and Macnab, 2000; Miller, 2003).

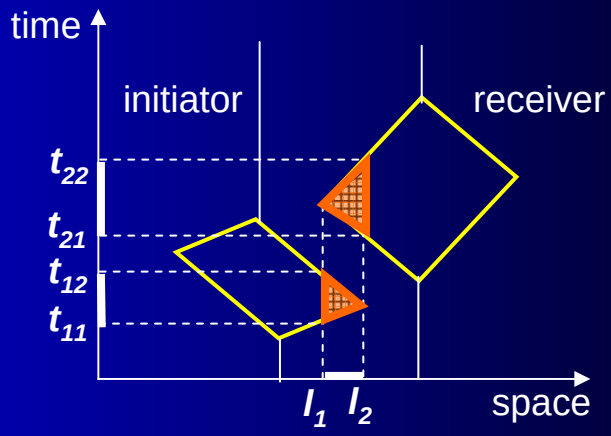
Temporal / Spatial	Synchronous	Asynchronous
Physical presence	**SP** (co-existence) ▪ Face-to-face meeting	**AP** (co-location in space) ▪ Fridge note ▪ Traditional hospital charts
Tele-presence	**ST** (co-location in time) ▪ Telephone ▪ Online chat rooms	**AT** (no co-location in either space or time) ▪ E-mail ▪ Web pages

(Adapted from Miller, 2003)

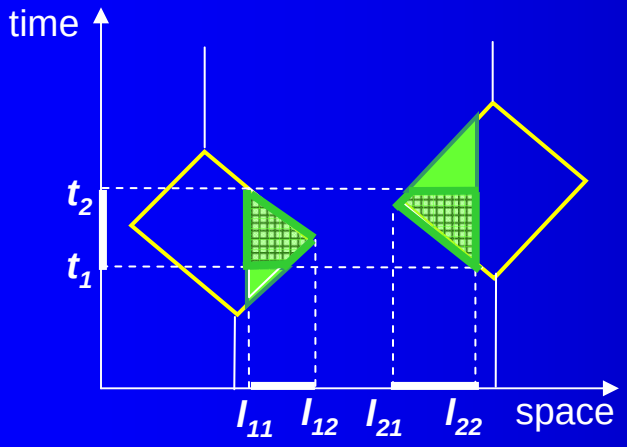
Spatio-temporal Relationships of Prisms and Potential Human Interactions



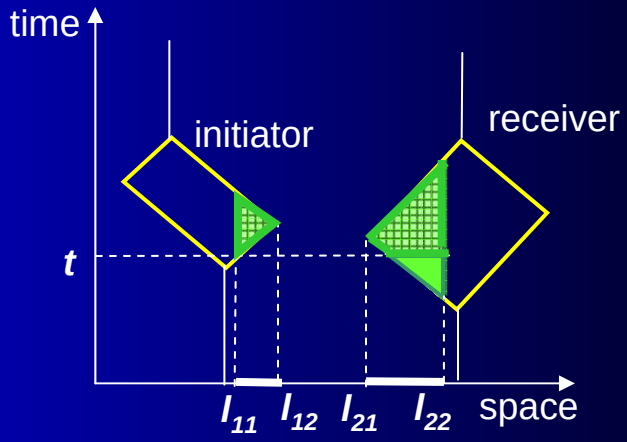
Potential SP interactions



Potential AP interactions



Potential ST interactions



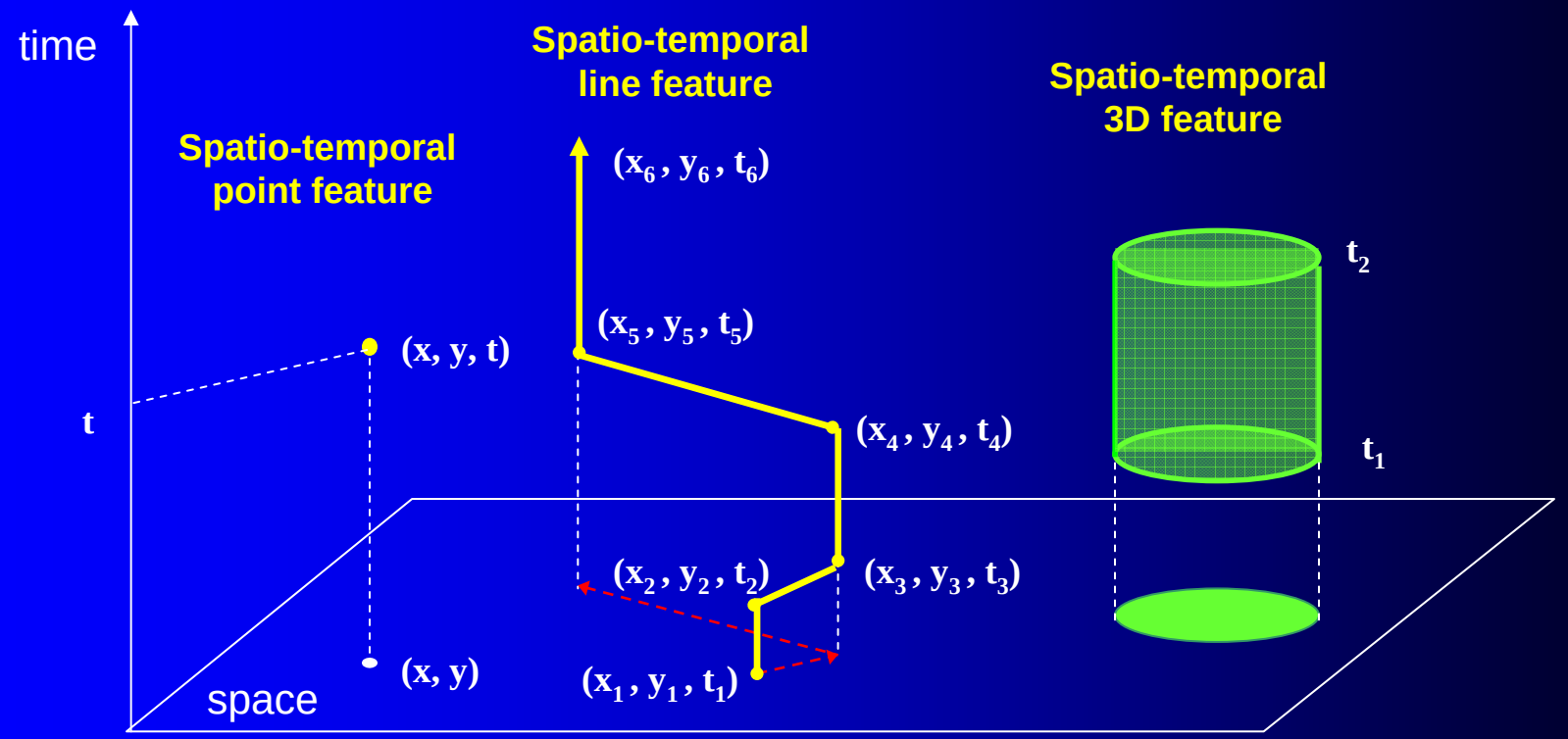
Potential AT interactions

Incorporating Time-geographic Concepts in GIS

- Miller (1991) first brought space-time prism concept into GIS and implemented network-based potential path areas (PPA).
- Recently, additional efforts have been made to apply time-geographic concepts in GIS (e.g., Kwan and Hong, 1998; Miller 1999; Miller and Wu, 2000; Weber and Kwan, 2002; Kim and Kwan, 2003; Weber 2003).
- Representation of space-time paths and prisms in GIS remains a research challenge (Yuan et al., 2004), especially for situations of handling both physical and virtual spaces and analysis of interactions among individuals.

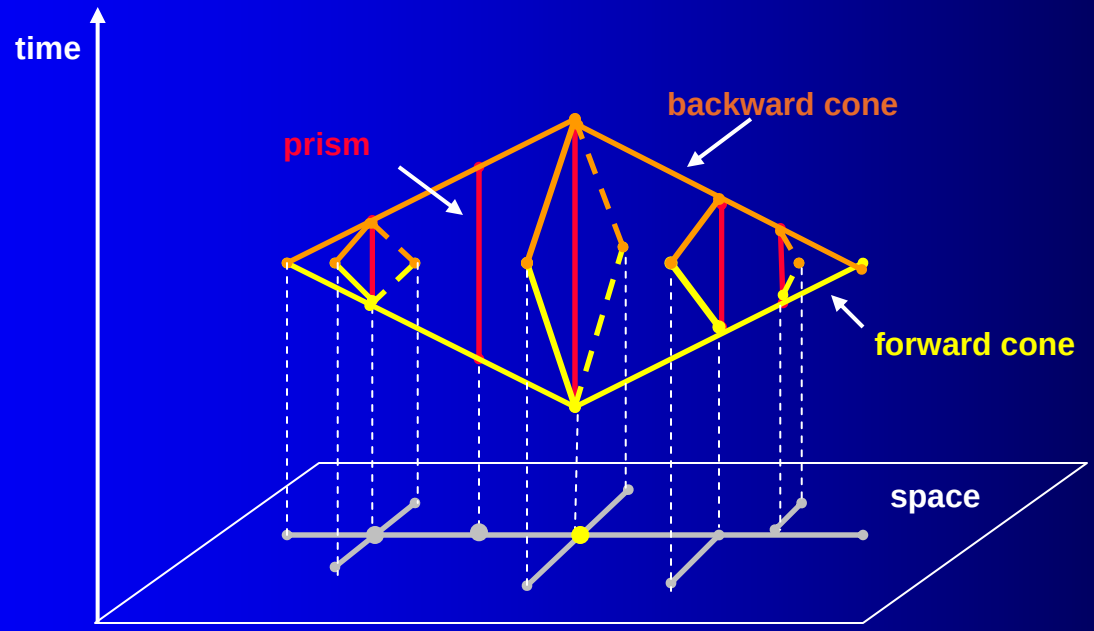
A Spatio-temporal GIS Design for the Extended Time-Geographic Framework

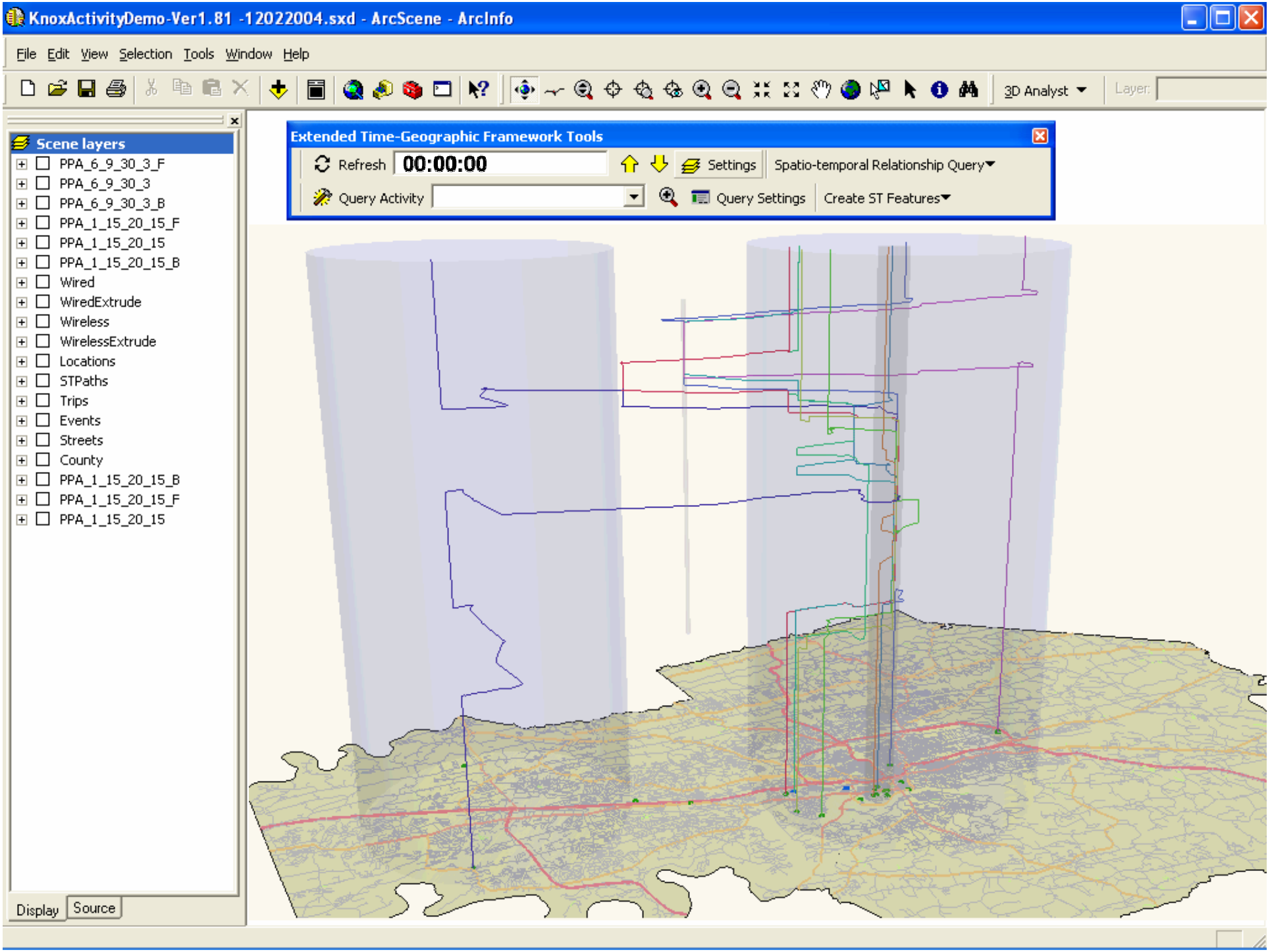
- Three-dimensional spatio-temporal features: 2D space + 1D time



An Explicit Representation of Space-time Prisms

- Forward cone/backward cone: the boundary of a prism
  - Represented as *a set of spatio-temporal line features*
- Prism
  - Represented as *a collection of vertical spatio-temporal line features*, which indicate activity opportunities at various locations with explicit time information.

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Query Activity
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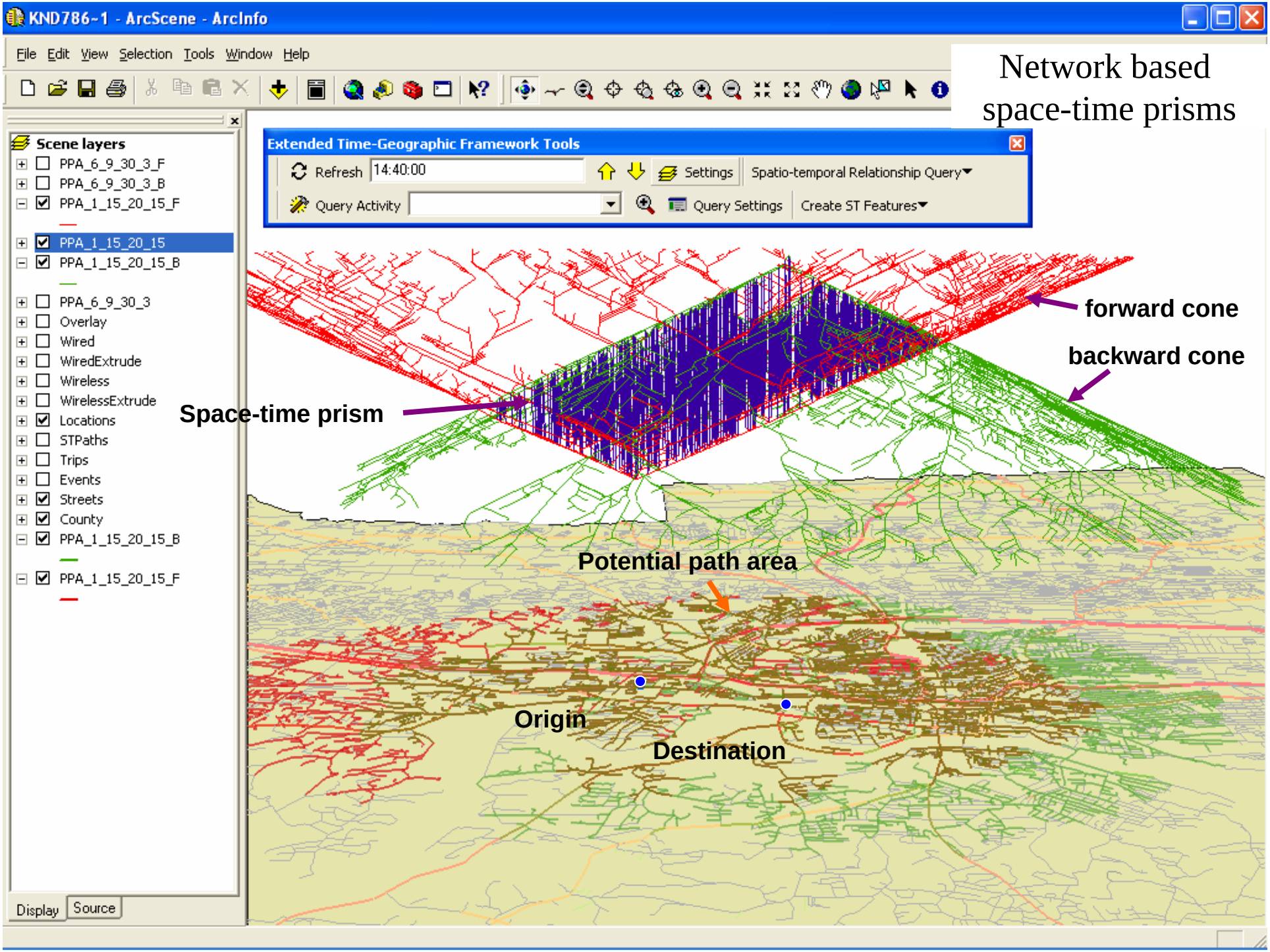
KND786-1 - ArcScene - ArcInfo
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Network based space-time prisms
Scene layers
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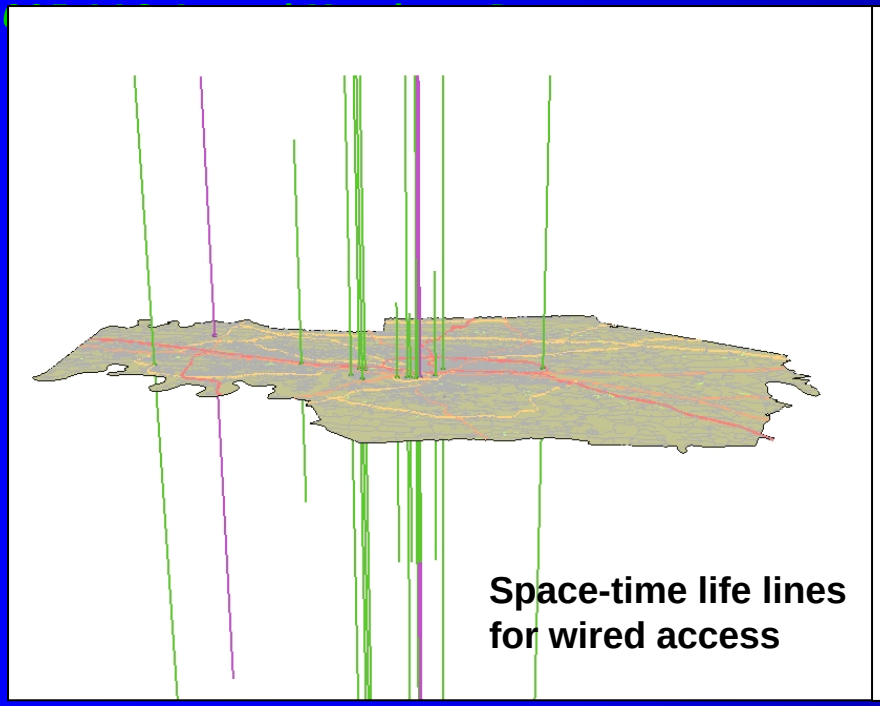
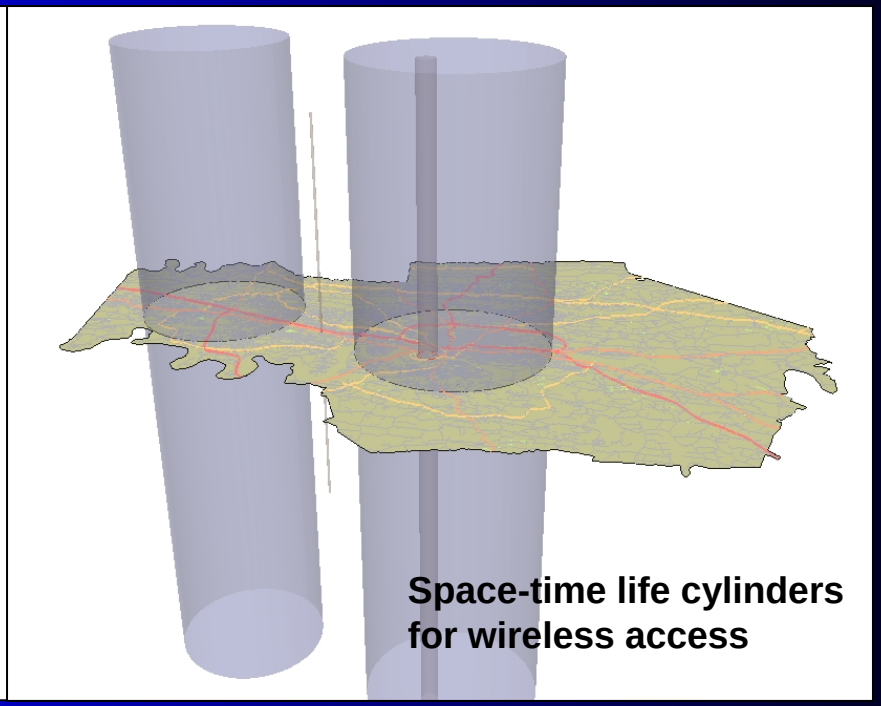
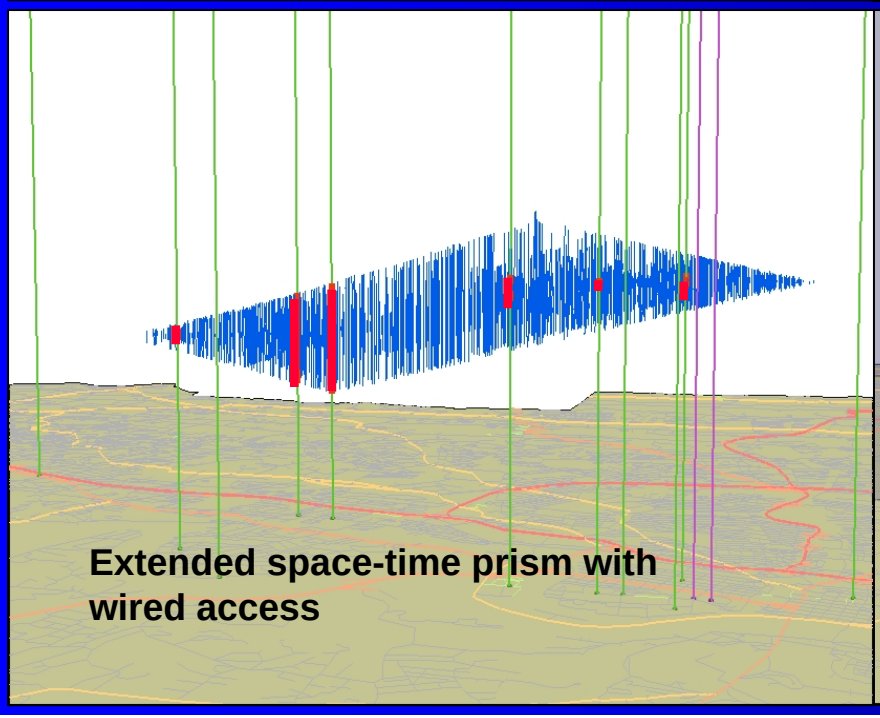
backward cone
Space-time prism
Potential path area
Origin
Destination



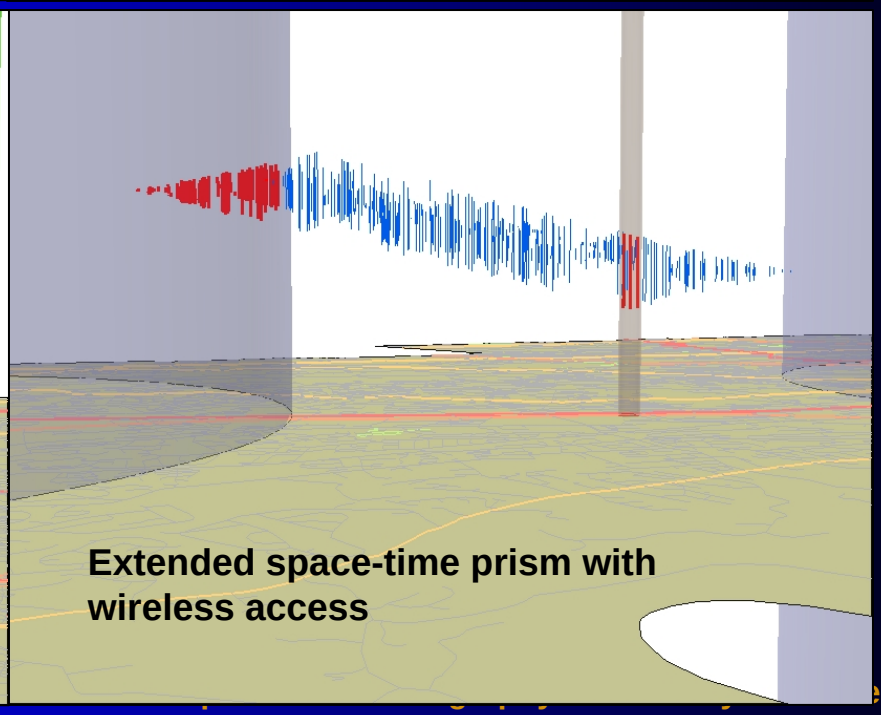
Space-time life lines
for wired access



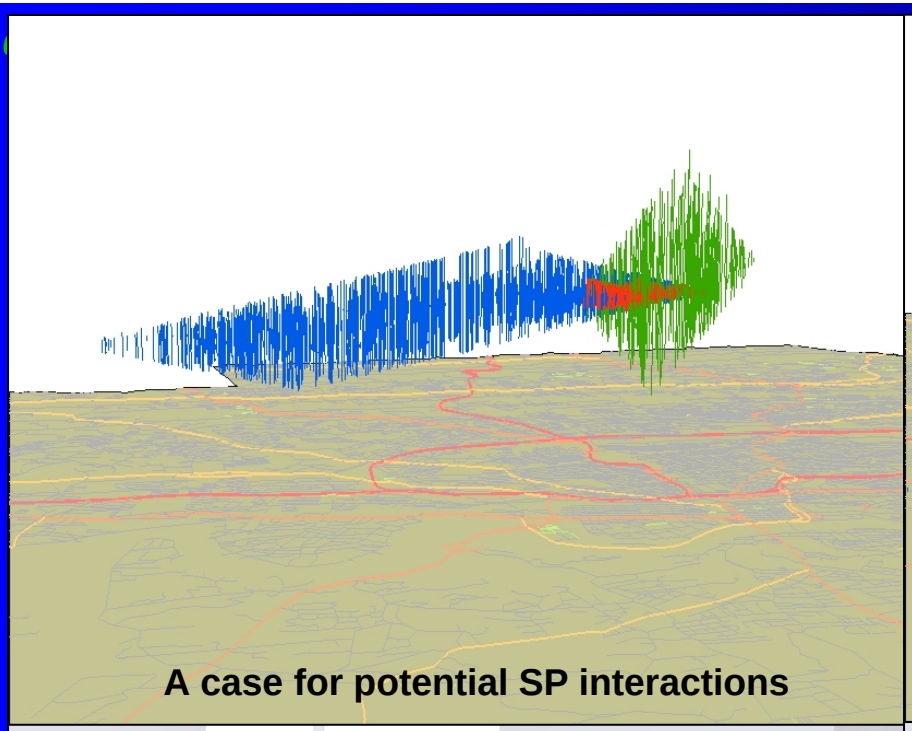
Space-time life cylinders
for wireless access



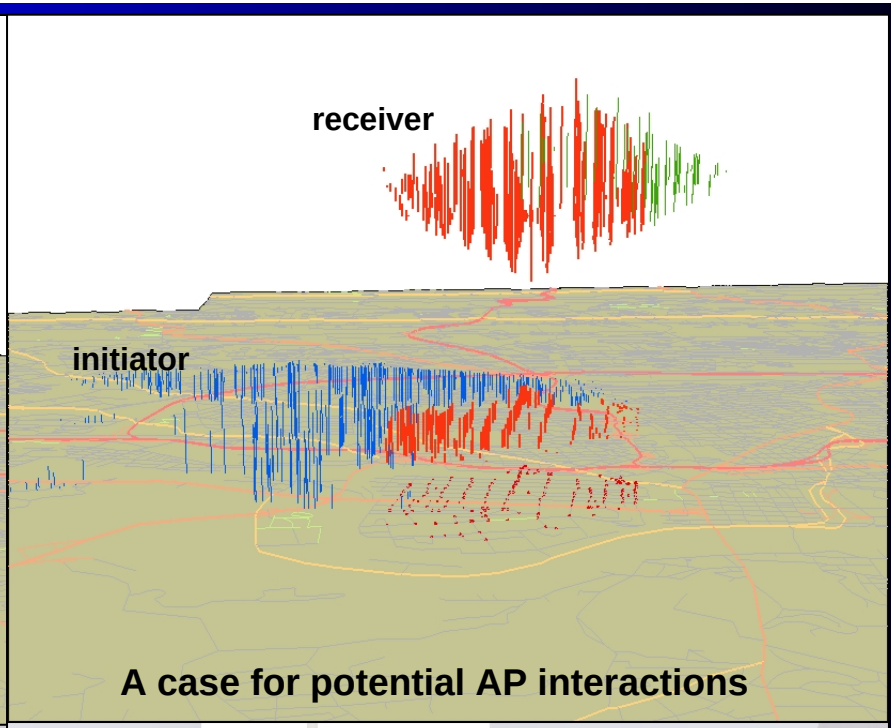
Extended space-time prism with
wired access



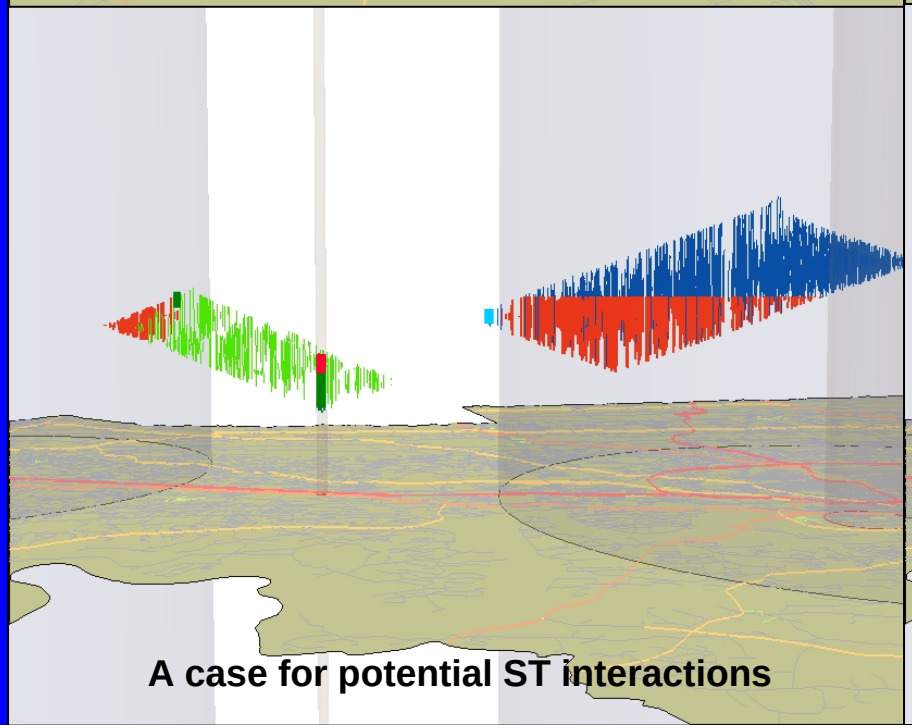
Extended space-time prism with
wireless access



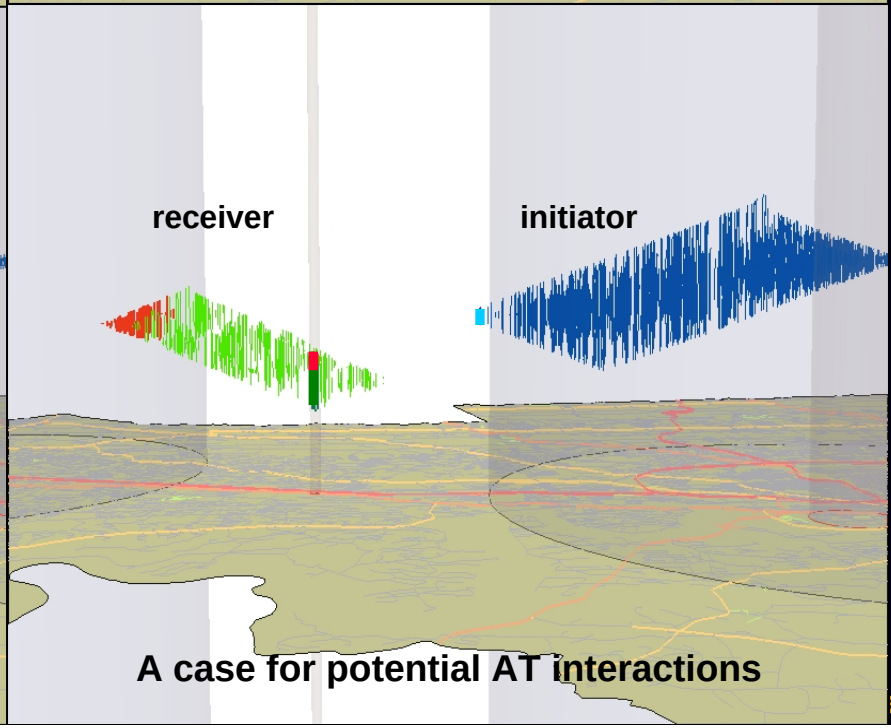
A case for potential SP interactions



A case for potential AP interactions



A case for potential ST interactions



A case for potential AT interactions

Summary

- Contributions of this study:
  - Extends space-time prism concept to represent potential human activities in both physical and virtual spaces;
  - Develops a spatio-temporal GIS design to accommodate the extended concept by providing functions to compute and visualize space-time prisms in a 3D GIS environment and to support analysis of spatio-temporal relationships among individuals; and
  - Offers an effective approach of dealing with spatio-temporal, individual activity data in a GIS environment.