

# Location Modeling for Ubiquitous Computing: Is This Any Better?

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## Introduction

Location is a powerful (even ubiquitous) concept. In the case of ubiquitous computing, there are two broad classes of needs that a knowledge of location serves: 1) location provides information about activity and intent, and therefore, the type of ubicomp support s/he may need, and 2) location provides information about the devices that are available to the user, which allows determination of what will be effective means of communicating with him/her. Since it is so widely applicable, we may sometimes attempt to use the location framework in areas where some other characterization may prove superior. We believe that for several of the functions of ubiquitous computing, this is the case. Note that there are many situations for direct employment of location-based reasoning: “where is the nearest railway station?”, or “how do I get to Restaurant Alma?”, or even, “how far is it to the airport?”. These geographic sorts of tasks are clearly unanswerable without reference to some underlying notion of location.

Consider, on the other hand, an experience many of us have had, yelling back and forth to correctly position an antenna, with the goal of maximizing signal strength delivered to the device from the antenna (“Is *this* any better?”). Whether this is the linear array of my youth, or the parabolic dish of my more recent experience, the point remains that location in the 3D sense is no longer adequate. Rather, we require a 6-DOF notion of location. It is, we think, entirely reasonable to place this “optimized connection” activity in the realm of ubiquitous computing location application questions. Drawing on the terminology used when someone asks, “How can I reach you?”, or the U.S. phone company advertisement jingle, “reach out and touch someone”, we will also refer to this optimized connection as “reachability”. We will consider several alternative statements of the “optimized connection” proposition that progressively become both more realistic and less concerned with location per se.

## Optimized Connections

### Signal Strength

In the antenna orientation example, an optimized connection amounts to maximizing signal strength. For any non-stationary case, it requires only the most trivial consideration to confirm that 6-DOF location modeling is not adequate to optimize the connection. As shown above, it is difficult enough when 3 of the dimensions are fixed to optimize a pointing angle. For any real-world ubicomp application, none of the dimensions are fixed. Further, simply using location, whether 3D or 6-DOF, is rarely sufficiently enlightening to provide information about how the client should move to improve the connection. This is particularly relevant in urban settings – witness the recent attempts to provide empirical validation of RF propagation models for Military Operations in Urban Terrain (MOUT) exercises.

Moreover, in my life, it is all too frequently the case that while my location is reasonably optimal, I do not have the appropriate adapter to obtain the desired bandwidth (PCS modem versus Wi-Fi, for example.) This is true, of course, whether the missing link is hardware, software or service. The local phone company provides PCS service that has wonderful signal strength at a coffee shop I frequent. Unfortunately, since they also have a significant dead zone that includes my home office, I do not subscribe, and the availability of signal strength does me no good.

### Bandwidth

Perhaps, then, it is *available bandwidth* that is the direct measure we wish to optimize, and location provides us an indirect means to predict the bandwidth value. We note in passing that location is a discontinuous function for this estimation, since the end of my hard-wired cable marks a significant decrease in bandwidth.

Again, a quick examination of personal experience reveals that bandwidth is not the appropriate measure. New (one wonders what that word means any more) adapters offer Wi-Fi connectivity for Visor and similar PDA-type platforms. I was even tempted to buy one, until I considered what conceivable use I would put my PDA to that would fruitfully apply the available bandwidth. After some contemplation, the list of applications (of length zero) was sufficiently convincing that I was able to put away my charge card (with the inevitable ensuing dejection). Clearly, there is some mediation effect that the control & display device exerts on the utility of the bandwidth [1].

### Device Capability

Have you read this far only to be told that what's important is what devices you can lay your hands on? **Everyone** knows that. No. In fact, obtaining access to the right devices isn't enough, in one obvious way, and another not so obvious. The obvious

way, of course, is information access. The appropriate information sources must be available, which we may take as a given in the WWW/Internet framework, but is less assured in environments that treat secure information, or that support legacy information sources.

The less obvious consideration is information suitability, or *relevance*. An example can be found in commercial flight decks, where there are a plethora of devices, but still the pilot may not have what she/he needs, because much of what she/he gets is not relevant to the task(s) at hand. This is the first class of needs mentioned above, that of “activity and intent” knowledge that location helps serve [2], [3]. Even here, we argue, a more direct clue is the task that the user is trying to perform. For example, a user is liable to require flight arrival time information if they are near their home airport, but the real reason they need the information is that they are performing the `Pickup<Mom, Airport>` task. The fact that they are near an airport is (merely) a highly correlated indicator.

## Task-Based Needs Determination

We assert that information, devices, bandwidth, and signal strength only matter when you want to do something with them, i.e., perform a task. What you want to do with them determines how much (and of what kind) you need. This is the second class of needs mentioned above, that of “device availability”. The remainder of this paper will focus on this class of needs.

## Quality of Service

Earlier, we talked about an “optimized connection”. That of course begs the question, “Optimized with respect to what?” We view the optimized connection as a service, one that is provided by the ubicomp infrastructure. The service is provided in order to satisfy a desire to transmit information that is task relevant. We have posited a number of characteristics or qualities that the transmitted information must possess in some measure. The qualities are:

- *Freshness*: How old is the information; how fresh does it need to be?
- *Reliability*: How certain is the information to get through to its receiver complete and intact?
- *Initiation Time*: How long does it take to initiate the connection to provide information?
- *Accuracy*: How accurate is the information with regards to world truth? How accurate does it need to be?
- *Resolution*: How precise does the information need to be?
- *Scope*: How much of the range of possible values needs to be conveyed?

For ease of reference, we refer to these abstract QoS parameters as the FRIARS values. FRIARS values are associated with: 1) information needs, and 2) the way in which information is delivered. As such, they provide a direct measure of how the

user needs the information to perform the task of interest, and how well the ubicomp system can provide (or receive) the information, given the currently available bandwidth, devices and information sources. The goal of the ubicomp system is to find information sources, devices, and bandwidth that satisfy the need with appropriate (matching) values for the qualities of service (QoS).

We note also that our candidate FRIARS parameters are related to, but expand and refine, the triad of abstract QoS parameters that Tom Lawrence [4] has advocated: Timeliness (refined as freshness and initiation time), Precision (refined as scope and resolution) and Accuracy (refined as accuracy and reliability above).

### **Task Specificity**

FRIARS values are specific to a task. Thus, for example, a `Review_Stock_Holdings` task will require greater freshness on the conveyed data than will a `Show_Available_Flights` task. In contrast, the `Show_Available_Flights` task has larger scope requirements (more of the time scale displayed) than does a `Show_Flight_Estimated_Arrival_Time` task. Thus, FRIARS values associated with a task will represent the QoS *requirements*, or target quantities on the information needs for that task. FRIARS numbers associated with a chosen display or control mechanism will measure the ubicomp infrastructure's ability to provide the desired information in the way it is needed for that task. This equivalencing of needs and capabilities definitions is required to compute "match" metrics which will be critical in performing optimization with regards to the conveyance of information (both display to the user and control inputs from the user) across all tasks the user is trying to perform.

In addition to these FRIARS values, we encode a weighting value showing the importance of that QoS dimension for that type of information for that task—that is,  $\text{Weight} \times \text{FRIARS value} \times \text{Task}$  (where the "X" denotes "cross", not the multiplication operation). These weightings show the relative importance of 'getting it right' for each of these dimensions—that is, how much latitude the ubicomp system should allow itself in meeting that information profile exactly as it has been stated. For example, while all tasks may have an initiation time value, some tasks may be very resilient with regards to deviations from that initiation time, while others may fail completely if they do not get their information by the initial deadline. When the match between desired and provided QoS over the FRIARS scales is maximized, we say that we have optimized the connection, or provided optimal reachability.

### **Location and Reachability**

Assuming access to a model of device locations and capabilities, user location information does provide good information about the type of device present in proximity to the user. This provides partial information about reachability. Next, the system requires information about what device capabilities are already in use (at some time  $t$ ), and thus what device capabilities remain. Finally, the system requires a model of what tasks need to be supported, the information transfer necessary to

support those tasks, and the qualities of service which need to be met to provide the information in a useful form. Together, these pieces answer the question of whether ubiquitous computing can be supported for this user in this location – whether the user is “reachable”.

## Conclusion

We have argued that for perhaps the principal use of location information in ubiquitous computing applications, namely the determination of access to bandwidth, devices and information sources and sinks, location is not a complete framework. Rather, location information provides an indirect measure of a more relevant metric, which we have referred to in this paper as “reachability”. This metric has quantifiable sub-scales that characterize your ability to achieve the desired level of connection service in each of the subordinate areas. The desired/required quality of service (QoS) in each of these areas is task-specific, as is the relative importance of achieving the specified value.

## References

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