INFORMATION CITIES OVER THE INTERNET; TAXONOMY, PRINCIPLES AND ARCHITECTURE

Jakka Sairamesh[1], Petros Kavassalis[2], Manolis Marazakis[2], Christos Nikolaou[2] and Seif Haridi[4]

[1]*Institute for Advanced Commerce*
IBM T. J. Watson Research Center
Hawthorne, NY, 10532
jramesh@us.ibm.com

[2]*University of Crete*
Heraklion, Greece
nikolau@csd.uoc.gr,
petros@rpcp.mit.edu

[4]*SICS, and Royal Institute of Technology*
Stockholm, Sweden
seif@sics.se

Abstract:

In the coming years, we expect many kinds of medium and large-scale information sites to emerge over the Internet, which will represent or mimic small and large "physical" cities. They will provide local and global information and services to registered inhabitants. Just like physical cities, these "information cities" (iCities) will house "infohabitants" who will participate in activities such as navigating the city, performing commercial transactions, socializing, and collaborating. We are already witnessing the emergence of large-scale web portals providing local information about cities, access to local government services, community services and a place for businesses to advertise and attract consumers on-line.

In this paper, we present a taxonomy of information cities; we classify them based on their characteristics and services offered. We draw analogies between information cities and physical cities. We describe our design criteria and present a middleware architecture for building an information city. Our goals are to understand the economic dynamics behind the creation, formation and survival of information cities, design mechanisms for social and economic interactions, suggest design principles for creating an information city, and build a prototype information city targeted towards a diverse community of infohabitants. We also present a prototype design of an information city.

1. Introduction

We are witnessing many kinds of information structures and sites emerging over the Internet since its birth in the 1970s. The excitement to build information sites and communication channels (email and email lists) started when Internet protocols were being designed by various groups of scientists and administrators separated by physical distance in the US and around the world. Since then, many types of scientific, social and economic networks, simple and complex, have emerged over the last 30 years, which provide a variety of services to individuals, businesses, social communities, non-profit organizations, municipalities, and societies.

Driven by profit and non-profit organizations, new kinds of information sites (e.g. large web-sites, supplier store-fronts, e-Marketplaces, Web-portals, community portals, Digital Cities and others) have emerged, and are still emerging. Some of these have many similarities to physical cities, except that the boundaries are not restricted by physical space or proximity, instead on the costs of participation, familiarity of navigating the city, search and transaction overheads, computational resources (e.g. disk size and processing power) and other frictional boundaries, which will limit the expansion of these information cities.

Most physical cities took many years and centuries to form [9], and they were constructed and expanded based on their economic structure and the needs of the inhabitants[1]. Very few cities have been planned or organized, and most of the current big physical cities evolved from being simple trading centers (e.g. fishing and commercial ports) to large commercial centers. Once the city was established as a trading center, the rest of the services such as social, community, municipalities and information services have emerged to satisfy the growing demand and the growing economy. There are other ways[2] in which cities have emerged, and different schools of thought have emerged on the formation and stability of these cities [9].

Similar to large physical cities, we see a trend in formation and evolution of large-scale information sites providing services to diverse participants over the Internet. Some of these information sites are evolving from being traditional e-commerce sites and web-portals to offering more complex, social and collaborative environments to participants. Unlike physical cities, these complex, "information cities", don't have a notion of physical boundaries. Some of these information cities boast a population of tens of millions of members or "infohabitants", larger than most physical cities. By infohabitants we mean humans and software agents participating and inhabiting the information city. These software agents could be performing tasks such as searching, navigating or alerting the human owner of activities in the information city.

Recently, new kinds of web sites focusing on local information have emerged. These are "local municipal information cities", owned by the local governments and municipalities of physical cities. These cities are showcasing their services to the rest of the world, and attracting businesses and attention from various users of the Internet. These information cities provide access to local government services, city departments such as law enforcement, police, department of transportation, birth-certificate departments, and so on. An example of such a city is Virtual New York (NYC.gov [17]), which is managed by the mayor's office. This information city provides direct access to 56 local municipal departments. NYC.gov was launched in 1995, and has since then attracted thousands (if not millions) of inhabitants of New York City and others to access New York City services.

For New York City alone, there are many for-profit companies that have established information cities to provide local information about New York such as: maps, events, news, weather, social events, simple discussion forums, email services, discussion groups, mailing lists, chat channels, travel information, and access to local government web-sites. Just like in physical cities, we can see on-line evidence and infer that competition among information cities is already happening in order to attract the attention of inhabitants, businesses, and organizations, and thereby survive over the Internet.

2. Project Goals and Approach

We envision a futuristic-world where humans and agents (representing humans) will inhabit information cities and interact amongst each other with other. By modeling and simulating such environments, we plan

[1] In this paper, infohabitants are inhabitants of an information city in the virtual space. City habitants are people habiting a physical city. In this paper, we interchange between infohabitants and inhabitants of an information city.

[2] Some cities were established by the rules of the king, who wanted a central place for administration, and some others were established as new cities to counter the old cities.

to demonstrate the emergence of various information macro-structures, i.e. agglomerations and other regularities, and socio-economic networks. Such aggregate outcomes are what are expected to happen, which are suggestive of *information cities*[3].

Our goals in the information city (iCities) project [23] are to model, design and prototype information cities. Some of the underlying questions we are seeking to understand are the following: What are the analogies between information cities and physical cities? What are the real-world examples of information cities? What are the factors causing the formation of information cities? What factors influence stability when information cities compete? What are the "equivalent" costs involved for inhabitants of an information city (similar to distance in physical cities)? What are the frictional effects and logical boundaries? What are the key design principles for medium and large-scale information cities? Models for information economies were done in [4] [25]. We plan to use similar models to understand agglomerations, specialization and aggregation in information cities.

2.1 Approach

The approach to our research work is in three-phases as illustrated in Figure 1.

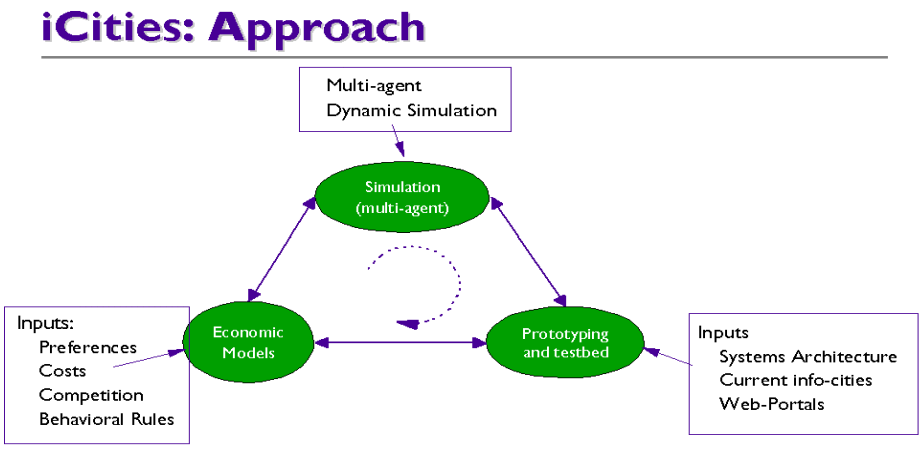

Figure 1. The three phase approach.

Economic Models: Our first step is to model behavior in information cities based on the activities of infohabitants in the current web-portals, where user-preferences, costs of participation, costs of advertising, competition among information cities and behavioral rules are taken into account. Our goal is to model and

[3] We expect that virtual agglomerations, or information cities, will be emerging in the future, inhabited by millions of participants or *infohabitants* (humans and software entities) involved in one or more activities. In the coming years, we expect many such *i-cities* to thrive over the Internet with millions of users interacting and participating in activities such as buying, selling, chatting, discussing, socializing and collaborating. Evidence of this is already clear with web portals and properties such as Yahoo, AOL-Digital Cities, MSN etc., which are providing innovative and differentiated services (ebay.com, amazon.com), huge e-business marketplaces (as BizProLink.com) and others, that attract millions of users everyday to conduct one transactions.

understand the dynamics of how information cities would be created, form structures and compete to attract various user populations based on the preferences of the infohabitants.

Simulation: In the second phase, we are using a simulation tool (Mozart [8], [24]) to investigate the dynamics of competing information cities, and user behavior. For the dynamics, we use a multi-agent simulation environment, where agents mimic the behavior of humans. Agents are programmed with simple well-defined rules. The agents execute these rules once the simulation begins [8].

Prototype and test-bed: We are currently building a prototype information city with mechanisms for socio-economic interactions. Once this is done we plan to deploy this site for various kinds of users. From the activity analyses of the interactions of these users , we plan to provide feedback to the models, and revise the models and assumptions. The design principles take into account issues of large-scale cities, scalability and "pluggability", where new kinds of inhabitants can easily join the information city.

3. Classification and Taxonomy

In the coming years, we envision many forms of information structures and community networks of various sizes, degrees and scales emerging over the Internet. We call these aggregations as information cities, which provide a home for many kinds of inhabitants, and provide a range of services for the inhabitants to interact, gather information, collaborate, work as teams, consult, publish information, and trade goods and services.

These "information cities" can be classified based on the services they offer in a multi-dimensional space, which is shown in the Figure 2. Large scale "information cities" such as Yahoo [19] and AOL [20] provide a combination of many services in order to attract consumers. In Figure 2, along each of the axes we represent the services, which vary in complexity. The simple services are close the origin of the axes, and the farther away from the origin are the richer and more complex services. For example, Yahoo mainly offers content services and community services such as e-mail, discussion groups and forums, and yellow-pages services.

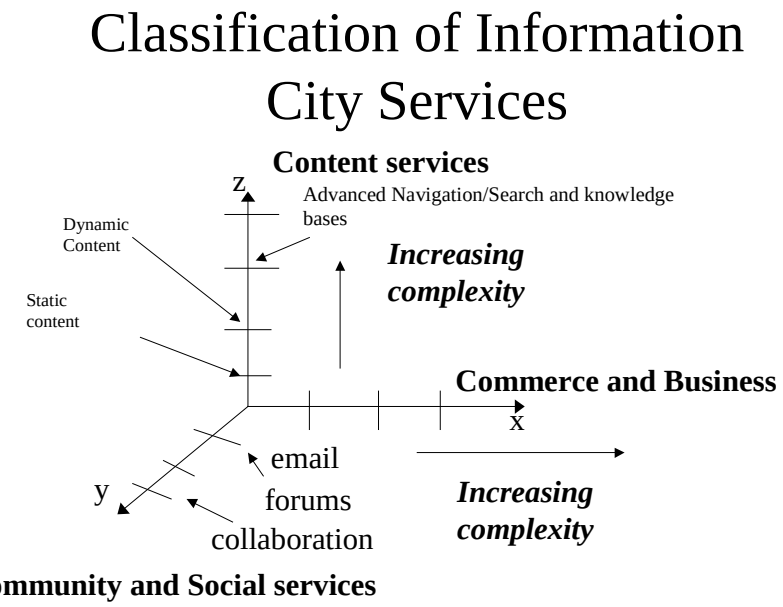

Figure 2: A three dimensional classification of services offered in information cities.

Using the above coarse classification, and details of each axis in the classification, we study the various flavors of information cities that current inhabit the Internet. A large body of literature exists on Digital Cities, and this is gaining momentum among many disciplines such as urban planning, computer science, architecture and others (Toru et. al [12], S. Graham[10], [11] and W. Mitchel[13], [14] and others). In this paper, we expand on the notion of information cities, where digital cities (which contain more local information) are one such kind of information cities. In the Webster dictionary, a city is defined as a "municipal corporation whose powers are confined to a fixed area and subject to the authority of the state". This definition, though simple enough, demonstrates that physical boundaries are the key to the physical cities, even though physical cities expand in a limited way[4].

We define an "Information City" as the following: a large internet-based web portal that offers a range of registered services such as access to information, social environments, community services, electronic commerce to its infohabitants (inhabitants). The boundaries are mainly limits on computational resources. Similar to a municipality of a city, an information city will generate trust from its infohabitants by providing "civic" and administrative services, and other services. For our research, we consider large information cities, which can support more than a million inhabitants. The inhabitants can be humans or software agents representing humans in the information city.

3.1 Taxonomy of Information Cities

We classified information cities in the previous subsection based on the services they offer to the "infohabitants". The classification, though coarse, provides a framework for comparing the range of services being offered by various kinds of information cities. The functionality of the services provides more insight into features to attract the users.

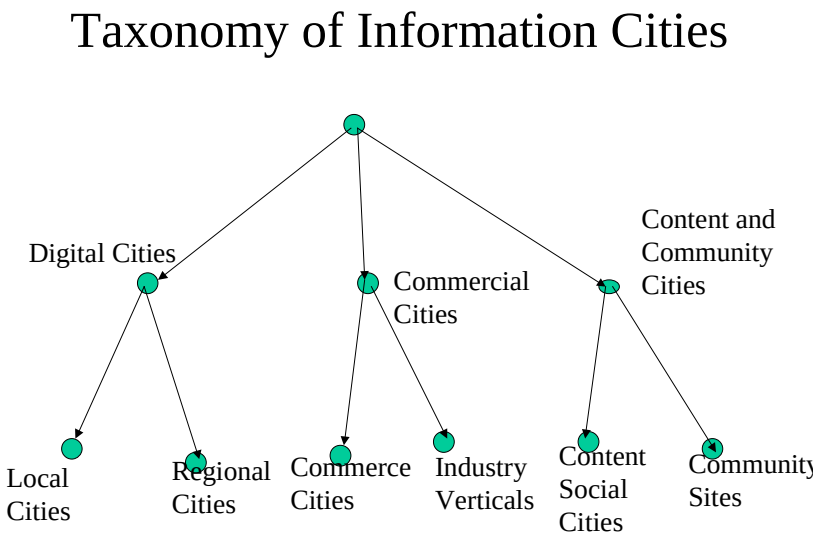

Figure 3: taxonomy of information cities

[4] One can argue that physical cities expanded by encompassing suburbs and local satellite cities. It has been shown that large cities tend to consume the smaller satellite cities. Similar effects will take place when an information city will consume another information cities in order to aggregate services.

The taxonomy shown in the figure is described below (starting from the leaves of the taxonomy tree).

1) Local cities: these are mainly clones of physical cities, providing information about an existing physical city to the physical city habitants. Some of these digital cities require some form of registration, just like in the physical cities. The revenue made by these cities is based on advertising. These cities are owned by local governments, which provide services for commerce transactions with the government (e.g. such as paying taxes, payment for city parking, accessing legal documents), and provide other information about the rules and regulations of the city, and access to public administration offices.
2) Regional Cities: a collection of digital cities represented through a single web site. Examples include AOL Digital Cities[20], CitySearch Digital Cities, Netherlands Digital Cities[16], and so on. These regional and national cities provide a common set of services to inhabitants interested in finding information about specific physical cities, such as weather, news, dating service, entertainment, ticket-ordering, information about local events, cultural events, social places, lodging and housing and so on.
3) Commerce Cities: These are established e-commerce sites such as eMarketplaces or Web-portals that provide a marketplace with industry news, and discussion forums for traders, and a wide range of e-commerce services such as auctions, catalogs, search, RFQs (request for quotes), reverse auctions, order management and payment services.
4) Industry verticals: These are large-scale web-based commercial portals that provide a common set of commerce services for buyers and sellers in many industry verticals. Examples include VerticalNet[21] and BizProLink[22]. These web sites offer a range of services from content to commerce to social collaboration among the traders: buyers and sellers.
5) Social cities: these are web sites for social interactions. They offer a range of information services and social interaction services such as email, chat rooms, discussion forums and others. Yahoo [19] and AOL are examples of such social cities. Many web sites set out to provide community services to specific interest groups, but over a period of time have evolved to offering e-commerce services and other content services. ICQ is another example of a social environment that has taken the Internet users by storm. It provided just the required social mechanisms for interactions.
6) Local information Community: These are these are public web sites, owned by the city or state that provides all the necessary information and community services to a specific community. These could be law and order in the community. Information about hospitals, emergencies and others that help the community at large.

Figure 3 shows the coarse level categorization of information cities. Digital cities offer local information and services to the local physical community mainly. Commerce cities are web sites offering e-commerce services to buyers, sellers and other intermediaries. Community cities are web centers for community information and social activities.

3.2 Examples showing the taxonomy and classification

In Figure 4, we illustrate the mapping of the various existing information cities, based on the services they offer in the multi-dimensional space. Yahoo began offering yellow pages services, organized a nice way, with simple hierarchical navigational functions. It then evolved to providing community services such as email, discussion groups, chat rooms, in order to attract more users, and providing them with free, but limited disk space and computational capacity. Yahoo as of now offers content, community and commerce services. It offers limited e-commerce transaction service, though it provide free-form auctions, shopping and businesses advertisements, business directory. Yahoo can be classified as a “global” city that offers very similar services as “local”, community-driven information cities.

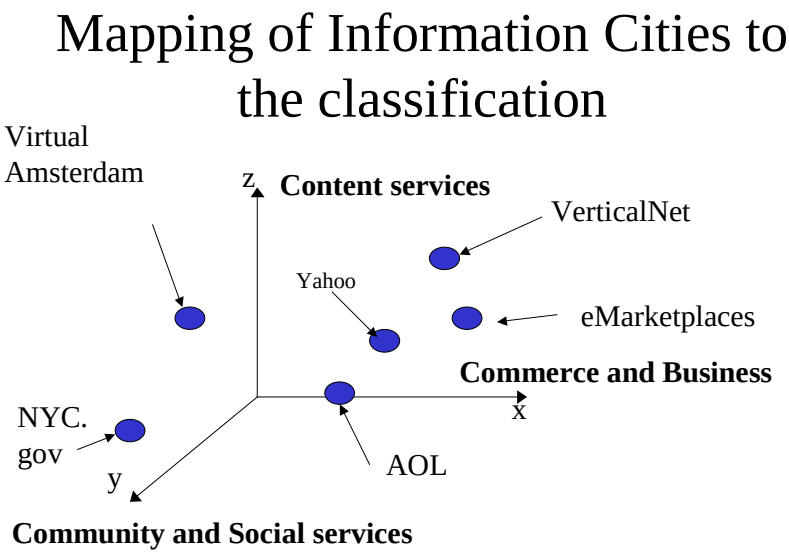

Figure 4. A mapping of the information cities on the classification of services offered.

4. Architecture

In this section, we present the crucial design issues for building an information city, which can support a variety of infohabitants such as: consumers, businesses, administrators, regulators, municipalities, mayors and others. We then present an architecture to support the various core services an information city.

Our core components are as follows for the overall architecture:

- Membership to allow multiple types of infohabitants to register and coexist in the information city, and allow them to play multiple roles in the information city.
- Mechanisms to register and profile new kinds of infohabitants based on the their roles and services offered. This involves registration, profile-creation and role definitions.
- Access control, where by infohabitants can control what profile and interest lists are public, and which are private.
- Mechanisms to support community and social interactions, so that infohabitants can communicate, discuss and socialize with business representatives, with friends and local municipal administration.
- Messaging interfaces and services to support a variety of fixed and mobile devices to communicate with the information city.
- A capability to define a “neighborhood”, similar in spirit with physical cities, where infohabitants of all kinds co-exist in the information space. The neighborhood is “virtual”, where many types of infohabitants coexist because of many reasons.
- Mechanisms to promote commerce amongst businesses and infohabitants registered at the information city.

4.1 Scenarios

In this section, we describe a few scenarios to illustrate the kinds of socio-economic activities in information cities.

Scenario1: Consider an infohabitant (individual or a consumer) registered at an information city. The consumer would like to navigate and find businesses interested in selling what the consumer wants. In addition, the consumer would like to search for his/her friends in the city to ask for advice on the product he or she is planning on purchasing. All this is done on-line in the information city. The consumer can navigate the city for businesses providing the required information, and in the process find a discussion group to get advice on the business and products offered or talk to friends in the city in order to seek advice.

Scenario 2: Considers another scenario where a business (infohabitant) registered in the information city, is looking for potential consumers. It could navigate the information city in parts to find the best possible match between what it is offering and what the consumers need. The navigation is either done by the business manually, in which case the multi-attribute search is applied within the navigational "window" of the info-city, which is similar to a business representative walking along a street in a physical city.

The navigation could also be done by a software-agent spawned by the business to search for potential customers based on matching criteria. The consumers who are match publicize their interests, and give permission to allow businesses and others to use that information to match. Once the match is done, the consumer could be notified by the business, and invited to participate in a negotiation process.

The two scenarios above illustrate that the consumers and businesses are using the directory services of the information city to find one another, and communicate with other inhabitants for advice on purchases. To support the two scenarios, the information city has to offer navigational services (manual and agent-based), directory services (e.g. LDAP[5] or UDDI[6]), matchmaking services, notification services, discussion groups, and others.

4.2 Design Criteria

There are many design criteria to consider when creating, developing and deploying an information city.

- Navigational services: Representation of infohabitants and their location in the information city. For this, many kinds of topologies of an information city can be chosen. The most common is a categorical group representation of infohabitants, like in Yahoo, but newer kinds of methods to navigate and gather information is a requirement.
- Customizability of content views and delivery: the generation of content must be customizable to different types of infohabitants in order to handle the various preferences. Content comes in various flavours such as businesses advertising product information and offerings, real-time news and content to interested parties, weather reports, content from archives, digital libraries (representing physical libraries) and other pertinent information.
- Authentication and session management: the server should handle mobile sessions similar to regular web-browsers for some applications. Authentication is to be done via Certificate based technologies using the standard directory services.
- Scalability: the information city server should be able to support millions of infohabitants living in its space. At any point in time, on an average thousands of infohabitants will access the information city for various reasons, and the application server and databases should be able to scale and handle the requests. In addition, when many requests come from large number of devices

[5] Light Weight Directory Access Protocol

[6] Universal Description Discovery and Integration

for trading in business-critical applications, the server must have the capability to handle content delivery in an efficient manner.

- Infohabitant member profiling and advertising: With mobile commerce evolving at a rapid pace [1], some of the participants at the e-commerce site (eMarketplace or sell-side server) will have more than one device, and they would like to use more than one-device to place-orders, and receive notifications. Advertising services (e.g. yellow pages) must be provided to capture the profile information, and help infohabitants find information about businesses, consumers and others.
- Matchmaking services: This is way to bring infohabitants together based on their advertised profile. Infohabitants of similar interests can be matched once they enter an information city. Likewise, businesses looking for consumers can be matched based on interest profile of the consumers and offerings of the businesses.
- User Interfaces for navigation. As a core design requirement, navigation should support various kinds of structures such as representing the city habitant space in 2D or hierarchical or in a hypercube structure.
- Mechanisms for social interaction: As a core design requirement, the basic functionality such as chat, discussion groups, public and private interest lists and other are crucial for establishing social networks in the Information City.
- Commerce functions. These include basic services such as setting up a catalog for a registered businesses, providing simple catalog based buying, auctions for trading and Request For Quotes for buyer requisitioning. In addition, billing and payment are required for fulfillment.

4.3 Architecture Details

4.3.1 Architecture

The architecture, shown in Figure 5, illustrates the various components in the end-to-end connectivity and commerce between various user devices and the information city application server. The figure 5 illustrates the types of infohabitants that would inhabit the information city. The information city server is a computer-system, which supports a complex middleware to handle a variety of requirements. Designing and building an information city is a complex task, as many components have to be put-together, and the city itself will be a collection of servers, including connectivity to businesses that already have web sites.

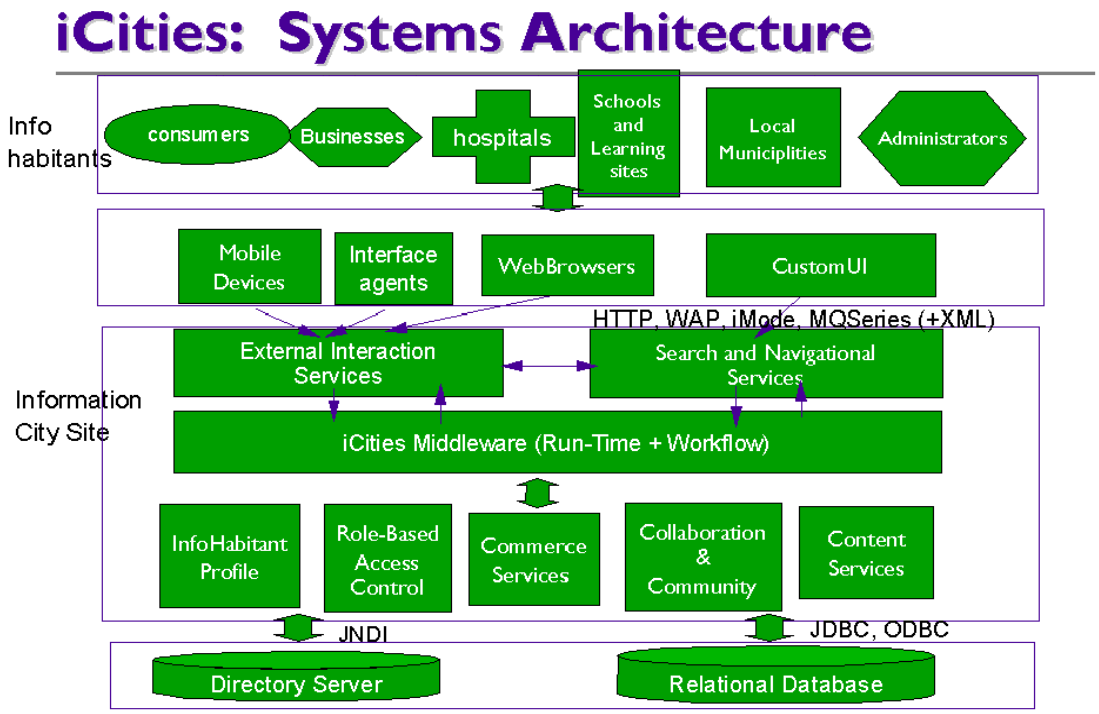

Figure 5: A detailed architecture of an information cities web site with various infohabitants.

4.3.2 Navigational Services

In Figure 5, above, we present the navigational services as a core user interface component for the end user or participant in the information city. The navigational features include a simple text-based hyperlink navigation (hierarchical) or a 3-D based graphical user interface, which helps navigate the various information structures. The Information city will be a federated collection of information sites organized in an information space, where navigation and search is crucial for participants to find and communicate with other inhabitants.

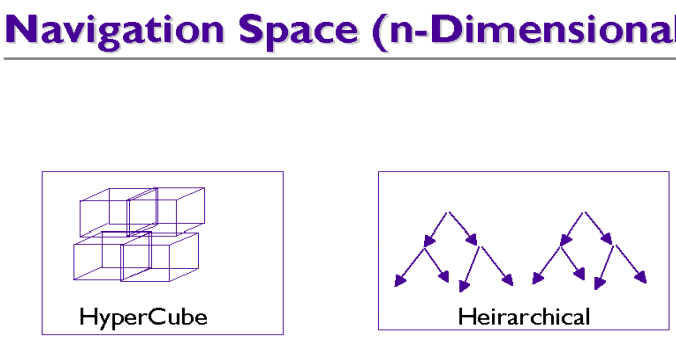

Figure 6: Navigational structures: (a) Hypercube 3D; (b) Hierarchical Tree.

4.3.3 Navigational Structures

Figure 6 illustrates two kinds of structures that could represent addresses or locations of infohabitants in an information city. The idea behind the navigational structures is to represent the city as a collection of roads (links in the hyper-cube or hyper-tree) and nodes (like squares in a physical city or intersections) in a multi-dimensional. All infohabitants live at these squares (nodes). So that during navigation, the user can view infohabitants in the neighborhood of the square (or node). The square is represented in 3D coordinates (x, y, z), and any business or residence at this square can be seen in the navigation. As the user walks from square to square in the 3D space, new information will be retrieved, thereby reducing the computational overheard and optimizing the database retrieval. The address of each infohabitant is a 3D coordinate.

Hypercube (3D): The nodes in the structure represent "intersections" of a "virtual road" that infohabitants can navigate to reach their final destination or simply search through the navigational space. Every infohabitant has an address, which is the node in a 3-dimentional grid, where the multi-dimensional coordinates represent the location of the homes, businesses and administrative offices. Just as in physical cities, where roads, maps and transportation are used for navigation, the information cities have addresses and profiles of infohabitants. The sample 3D (x,y,z) assignment, shown in the figure above, helps in quick navigation for any infohabitant. This is similar to the 2D (x,y) coordinate that exists in the "physical world" for finding residences and businesses and others. The office address, which is in the (z plane) provides the actual location.

Hierarchical: This is simply the category based navigation, where consumers, businesses, administrators and the rest are structured under categories such as "consumers", "homes", "businesses", "local government", and so on. The model is similar to the structure in "Yahoo" and others. This represents a simple way to navigate a "tree" like structure, but it does not provide the necessary location for each business.

The infohabitant navigating the info-city can always submit a search, but that would mean searching a large space, and the results returned won't be structured, and would be too much to navigate. In order to avoid this, we chose the structures, described above, which make navigation easier and within the context of the what the infohabitants wants to observe. With sophisticated matchmaking services, the profiles of the participants and businesses can be searched to good degree of accuracy and response time.

4.3.4 Interaction and Mobile Services

Given the advances in mobile computing devices such as advanced internet phones, PDAs, hand-held computers, the access to the information city does not have to be just through a web-browser (located on a desk-top or lap-top), but could also be from a mobile device, where information delivery is limited, but accessibility is from everywhere. In addition, access could be through messaging (e.g. XML, SOAP or structured email). Many new mobile applications based on location have emerged recently for navigation in a city or town with GPS enabled maps and information about community and commerce for each specific region.

4.3.5 Infohabitant types

Each infohabitant is represented by a profile in the information city. A part of the profile is made public by the registered infohabitant. The meta-data for each infohabitant, specifies the name, location (3D or 2D), a list of interests, ways to communicate, and other user specific public information. Similarly, a business will have a searchable business profile. The public information of the metadata is available for yellow pages and other kinds of search and navigation engines. Some of the infohabitant types are defined as follows:

Businesses: These are commercial small, medium and large enterprises with representations in the infocity. They are registered to participate in the infocity for attracting transactions from other businesses and consumers. Businesses specify their profile when they register. Businesses can specify their roles, the parts of the profile that is public, and parts that are private, and parts that are viewable by specific businesses or consumers.

Consumers: These are registered users of the system, who have a profile of their own. Consumers specify their interest profile when they register. They can edit their interest profile, and specify which parts of the interest profile are public, which are private, and which are viewable by friends.

Schools: Learning centers for education for all kinds of information consumers. The on-line learning centers will provide education services, collaboration with the teachers, education course material, and also transactions for fees to participate in the learning courses. Some will be free learning courses, but the others will be fee based, and will support several levels of quality of service.

Administration: Information city management officials who administer the information systems that support the information city.

Municipalities: These are representative departments of the local government who participate in the information city to provide the necessary physical city services to the infohabitants.

4.3.6 Metadata for Infohabitant Membership Profile

For user-profile (individual infohabitant) and business profile, metadata for their profile is captured when registering. The user can advertise parts of the profile to be visible to the public, and the rest private, and some parts to specific groups of infohabitants(e.g. friends). The profile for user is given in the table below.

Attribute Name	Description
Infohabitant Name	The name of the consumer
Email Id	Email address
Role List	Consumer could have many roles in the information city
Interest Profile	A profile of interests for attracting other infohabitants. This could be a private or

	public profile, controlled by the infohabitant
Notification Preference	The preferred notification channel. This can be made public or private
Product Interest	A list of products
Friend List	A list of friends, and their contact addresses within the information city
Coordinates	The location of the infohabitant within the information city
Physical Address	The physical address of the infohabitant in the physical city.

The metadata for the businesses is shown in the table below.

Attribute Name	Description
Business Name	Name of the business
Type	The type of business category: such as ceramics, hotels, airlines, financial, banks and others
Interest Profile	Interest profile
Offerings	Catalog of business offerings
URL	URL for finding the business web-site
Coordinates	The coordinates in the information city
Contact	Contact information, such as name and address
Notification	Preferences in notification
Role	The various roles in the physical economy: supplier, manufacturer, distributor and so on

4.3.7 iCities Middleware Runtime

The middleware layer consists of many sub-components (which are not shown in the figure). The middleware handles the various interactions between infohabitants and services offered within the information city. The middleware layer support is the backbone of the city server that provides access to the databases of city information.

For the implementation, the middleware layer components are services offered by the Web Application servers such as: Java run-time, workflow, messaging, database transactions, access to directory server (through LDAP or UDDI[7] protocols). With the emerging standards on Webservices, the creation of universal directories and communication protocols and data formats (XML) such as SOAP will provide the base for standards-based platforms.

4.3.8 Directory and Advertising

One of the core components is a simple directory service containing a list of participants, and their profiles. An LDAP (Light Weight Directory Access Protocol) or UDDI is the main server for infohabitant profile management. Advertising the profile or parts of the profile are crucial to finding infohabitants with similar interests. Matching making algorithms such as “stable roommates”, “weighted matching”, “muti-attribute

[7] UDDI stands for Universal Description Discovery and Integration

matching" and others are being used to provide a range of services to match profiles of infohabitants with common interests.

4.3.9 Commerce Services

These services are many and complex. There is substantial body of literature on e-commerce services. In this subsection, we simply list the common set of services required for transactions between any two parties.

- Negotiation services: Auctions, Request for Quote, Catalog-based trading, two-party interactions and others.
- Matchmaking services: Matching of consumer interest profile in products and business offerings.
- Payment services: A collection of payment mechanisms, and ways to specify the payment terms and conditions after a negotiation.
- Catalog services: A set of indexing and searching services for businesses to advertise their products and services. The catalog provides a focal point for consumers to find the offerings by the various businesses, and negotiate on the products from one or more businesses.
- Escrow services: Once a negotiation is done, if a consumer prefers an escrow service to ensure fulfillment and delivery of the product requested.
- Banking services: For financial guarantees and payment services, banks provide the necessary
- Collaboration: For discussion between buyers and sellers, simple collaboration tools which can track activities, and provide collaboration facilities for after purchase interactions.

4.3.10 Content Services

Organizing content services in large information cities is a challenge. Most content is organized by owner, but the metadata used by the various content owners could differ based on the context. Search and indexing of multi-media content is crucial to help identify and retrieve content. Metadata to help in indexing the content in many different ways. In the coming years, we expect many infohabitants to participate in the information city using mobile devices such as internet-enabled phones, PDAs (personal digital assistants), hand-held computers and other devices. The architecture supports simple content switching capability based on the device type and the session context of an infohabitant in the information city.

4.3.11 Community and Social Services

The range of services for community interactions:

- Matchmaking services: a service that can help infohabitants establish social networks that have similarities of interest.
- Discussion groups and email: This provides the very basic communication capability and discussion groups provide a simple forum for discussion.
- Chat channels: These are services for leisure chats and non-structured or indexed information. Most of them are private channels of discussion among close friends.
- Tools for capturing social activities: Interest lists, calendars and other tools provide the necessary support for sharing interests, and thereby finding individuals with similar interests in the information city [26].

5. Prototype Information City

An early design and prototyping effort is underway at the University of Crete (UoC) to build an information city connecting many different departments of University of Crete, and provide services to students, academic staff and administration interested in various activities within the university.

The prototype, though a modest one, captures the key design requirements for an information city. The prototype maps resources and processes of the University in an electronic landscape inhabited by software entities (infohabitants) that represent University community members, resources, as well as short-lived entities such as courses, projects, and events. Community members include students, instructors, and administrators. The prototype information city aims to provide an infrastructure for the diverse learning communities fostered in the University environment, including courses, projects, events, as well as informal "special interests" groups. Figure 7 illustrates the electronic landscape enabled by the prototype.

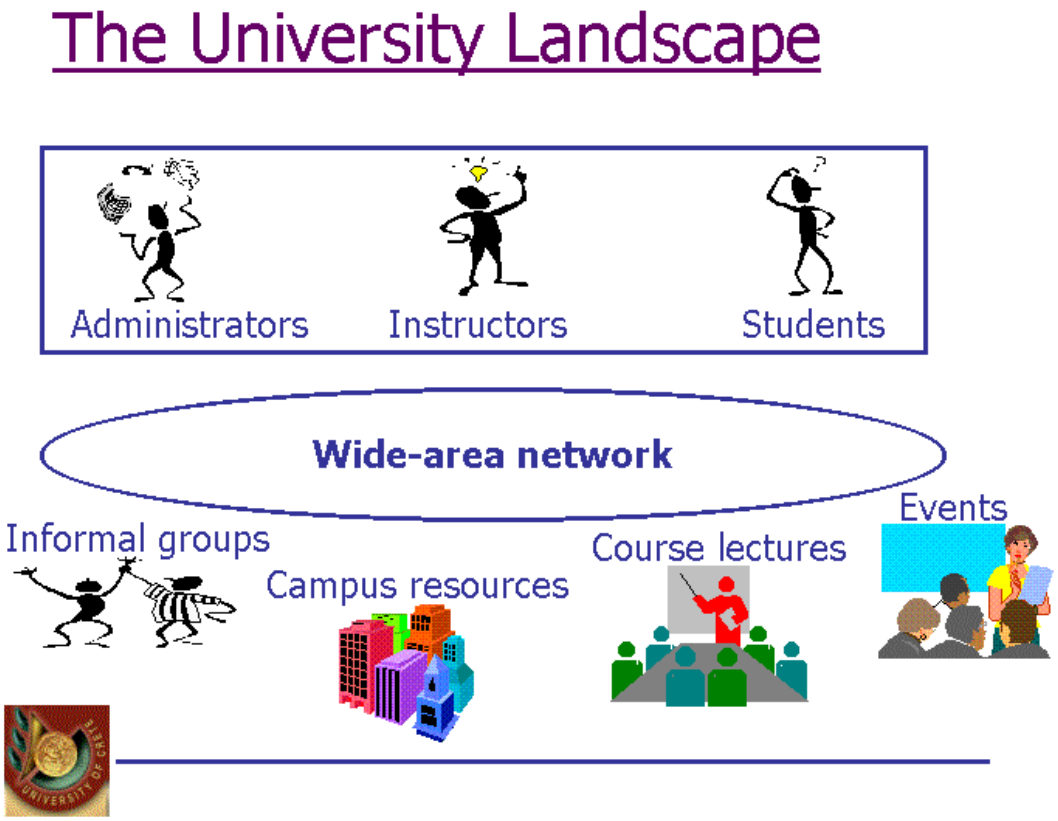

Figure 7: Prototype of an information city: The UoC Landscape.

The prototype can be seen as an electronic marketplace where entities interact in the context of match-making processes that aim to satisfy the demands of community members by pointing them to appropriate resources and services. It is important to note that this marketplace goes beyond simple buy/sell transactions as it drives the creation and evolution of dynamic groups (clusters) of entities with matching interests and/or needs.

From the instructors' point of view, this marketplace supports their two main responsibilities: course design and course management. Educational material, eligible for inclusion in a course syllabus, is organized in self-contained units ("modules") that can be dynamically selected from collections and assembled in order to form a course syllabus. In the prototype, software entities representing modules actively seek to be parts

of a course, by registering themselves in directory services that in turn can issue notifications about their availability. Likewise, for the purposes of attracting an audience, software entities representing courses take active steps for announcing course availability, again using the infrastructure's directory services.

From the students' point of view, the electronic marketplace enabled by the prototype provides support for selecting courses, by allowing them to discover what is available and by whom, as well as by pointing them to other resources or material of interest and other people interested in the same subjects. Software entities representing students discover resources that may be of interest, as well as interaction opportunities with other individuals, either directly or in the context of groups. Groups may be focused (such as course- or project-oriented) or informal (such as friends, associates, and special interests).

From the administrator's point of view, the prototype offers an infrastructure for supporting learning communities. This view of the University as an infrastructure allows administrators to control access to resources and services available in-campus or from external sources (such as peer institutions, public authorities, and private enterprises). From their point of view, the University is also a broker for services, facilitating the discovery and exploitation of available resources and services. More importantly, the infrastructure offers mechanisms for quality control and enforcement of standards and regulations regarding the rules of conduct by University community members.

These complementary viewpoints of the University rely crucially on the notion of trust. The prototype offers a computation framework that allows the quantification beliefs regarding attributes of entities (such as persons, services, courses, and other high-level objects of interest to members of the University community). Examples of attributes include reliability, quality, appeal, timeliness, trustworthiness, and other qualitative aspects of entities. The trust computation framework allows for subjective viewpoints of trust, as each entity forms and maintains its own valuation of a given target entity's attributes, as well as for propagating trust valuations to entities that have issued requests for recommendations. Trust computations allow entities to review trust valuations over paths spanning multiple recommenders.

Trust computations allow entities to prioritize the candidates for selection or interaction whenever such a decision is to be made, thereby enabling automation in a highly dynamic environment. Since trust computations are subjective, in other words not necessarily shared by two or more entities, and dynamic, in the sense that they rely on a messaging protocol for propagation and update, the trust computation framework captures the dynamics of interaction in the electronic marketplace for services. Trust computations produce vectors of numeric values, where each value represents a quantification of an entity's valuation of a specific attribute of a target entity. Each individual entity may classify a target's "quality" by applying straight-forward threshold criteria.

The trust computation framework is a central part of the prototype, as shown in Figure 8. Current work towards the development of the prototype involves finalizing the formal definition of the trust computation

framework, as well as a formal definition of "distance" in the vector space defined by trust valuations.

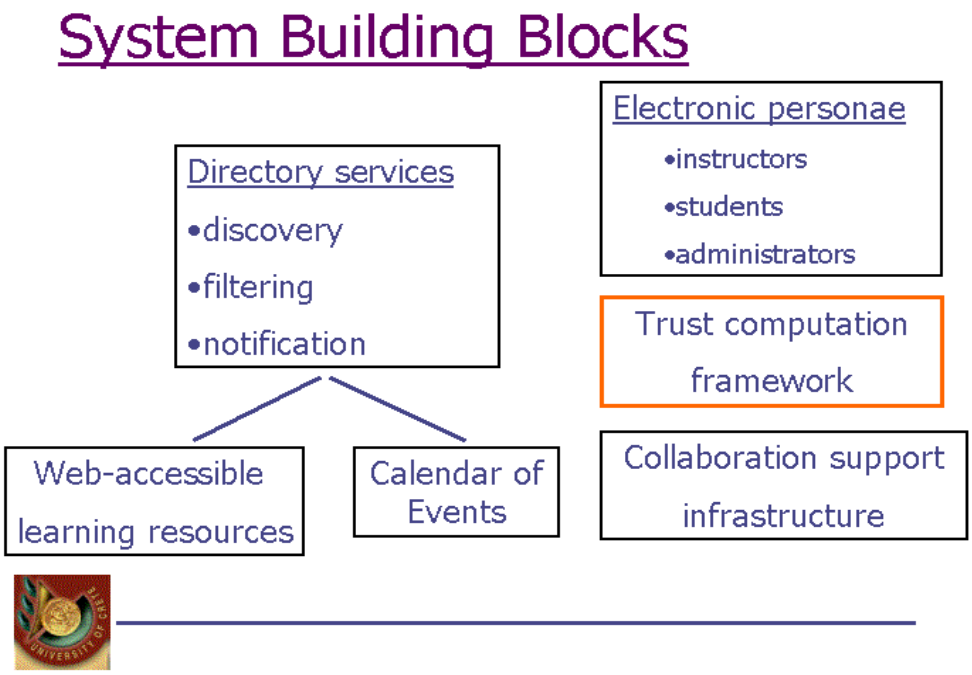

Figure 8: Prototype building blocks.

The definition of "distance" is required for a geographical interpretation of the electronic landscape realized by the prototype. This interpretation is seen as a basis for navigational services to be incorporated in the prototype.

6. Summary and Conclusion

In this paper, we presented a taxonomy of information cities based on their structure and services offered to the various members (infohabitants). We also classify the information cities based on the service offerings to the infohabitants. The classification and taxonomy provided the necessary feedback and understanding of the design criteria for building medium to large scale, complex, information cities.

We presented a detailed architecture of an information city server that will support a wide variety of infohabitants, and provide the necessary services for content searching, navigating the city, commerce transaction and community services. We proposed a collection of core components of an information city for fostering socio-economic interactions: directory services, advertising and profiling of infohabitants, access control, navigational structures, navigational user interfaces, connectivity to all kinds of devices, support for community interaction, commerce transactions and content indexing and delivery.

Our approach is to use high-performance databases, and open directory servers (e.g. UDDI), and web-application servers to prototype information cities. We also presented our prototype architecture, which is currently under development for a large university consisting of diverse set of infohabitants. The prototype illustrates the some of key components being used for an information city. Information cities are emerging and will continue to emerge to provide local information and social environments to foster active socio-economic interaction amongst infohabitants.

7. References

1. Durlacher Research Ltd. “Mobile Commerce Report”, February, 2000.
2. O. Granstrand. “Temporal Diffusion and Population Dynamics : A Systems Model”, in. N. Nakicenovic and A. Grubler (eds).Diffusion of Technologies and Social Behavior. 1991. Springer-Verlag Lecture Notes in Computer Science.
3. J. Sairamesh and J. Kephart, “Price Dynamics in Vertically Differentiated Information Markets”, proceedings of the ICE-98 conference, and Springer Verlag Lecture Notes in Computer Science, 1999.
4. S. Wasserman and K. Faust, “Social Network Analysis”, Cambridge Press, 1999.
5. D. J. Watts, “Small Worlds”, 1999, Princeton University Press.
6. P. Krugman. The self-organization economy. 1996. Blackwell Publishers, Inc.
7. M. Fujita, P. Krugman and A. Venables, “The spatial economy: Cities, regions and international trade”, 1999. MIT Press.
8. P. Kavassalis et. al., “Regularities in the formation and evolution of Information Cities”, submitted to the Symposium on Digital Cities, Kyoto, Japan, 2001.
9. J. Jacobs, “The Economy of Cities”, Vintage Books edition, published by Random House Edition, 1970.
10. S. Graham, “Cyberpsace and the City”, 1995, Journal of Town and Planning.
11. S. Graham and A. Aurigi, “Virtual Cities, Social Polarization and Crisis in the Urban Public Space,” April 1997, Journal of Urban Technology.
12. T. Ishida, “Understanding Digital Cities”, in Digital Cities: Technologies Experiences and Future Perspectives, 2000, Springer Verlag Lecture Notes in Computer Science.
13. W. Mitchell, “e-Topia”, MIT Press, 1999.
14. W. Mitchell, “City of Bits”, MIT Press, 1996.
15. T. Ishida, Community Computing and Support Systems, Springer-Verlag, Lecture notes in Computer Science ,1997.
16. Virtual Amsterdam, www.ddl.nl
17. Official New York, www.nyc.gov
18. Boston Online, www.boston.com
19. Yahoo Inc, www.yahoo.com
20. America Online, AOL and Time-Warner, www.aol.com
21. VerticalNet Inc, www.verticalnet.com
22. Biz Pro Link Inc, www.bizprolink.com
23. Information Cities Project, Project no: IST-199911337, Brussels, Belgium. URL: http://icities.csd.uoc.gr.
24. S. Haridi et. al., Programming Languages for Distributed Applications, New Generation Computing, 3: 223-261, Omsha Ltd. And Springer-Verlag, 1998.
25. J. Kephart et. al., “Information Filtering Economy”, proceedings of the ICMAS’98.
26. Y. Jung and A. Lee. Design of a Social Interaction Environment for Electronic Marketplaces. In Proceedings of DIS'2000 - Designing Interactive Systems: Processes, Practices, Methods, Techniques, ACM, pp. 129-136, 2000.
27. P. Kavassalis et. al., “Dynamics of the Evolution of Information Cities, Proceedings of the 5th Congress on the economics of Telecommunications and information technologies, Madrid, June 14th and 15th, 2001.