Auranet: Trust and Face-to-Face Interactions in a Wearable Community

Jay Schneider, Gerd Kortuem, Dustin Preuitt, Steve Fickas, Zary Segall
University of Oregon
Deschutes Hall
Eugene, OR 97403 USA
{jay,kortuem,preuitt,fickas, zs}@cs.uoregon.edu

ABSTRACT
This paper continues our work on wearable communities. We examine one facet of a wearable community, the Auranet, a framework for structuring encounters in social space based on reputations and trust.

Keywords
Wearable computing, CSCW, agents, trust, reputation, peer to peer.

1 INTRODUCTION

Our modern world is characterized by an ever increasing number of electronic devices augmenting every aspect of our daily lives. These devices range from cell phones and PDA's to full fledged wearable computers. These devices are always with us, always on and aware of many aspects of their environment. They are with us at home, on the street, in stores and in restaurants.

Our daily lives are also filled with human interactions when through chance or design we physically encounter friends and strangers. These encounters occur at places like coffee shops, grocery stores, and offices. We interact to trade news, tell stories, gossip and exchange goods or services. Often we use these meetings to pursue our personal goals. However, our electronic partners are silent in these encounters. Currently, when two individuals meet it doesn't matter if they have a Bluetooth enabled Handspring Visor, a wearable computer or no electronic devices at all, the interaction is the same. This opportunity for interaction is currently underutilized and is the focus of our *wearable communities* research.

With the introduction of short range radio frequency (RF) and mobile ad-hoc networks (MANET) our wearable devices can participate with us in these encounters. These face-to-face encounters form an ad-hoc peer-to-peer network that we call the Auranet. As with any group, users having daily interactions form social groups and whenever people form social groups they form communities. When these communities are augmented by wearable technology they become wearable communities.

This paper begins by presenting a scenario showing how life in a wearable community differs from the traditional model of cyborgs operating in a vacuum. These characters and their interactions help us illustrate our key issues.

We introduce our updated view of a wearable community based on the knowledge we've gained through working with the Auranet. We then proceed to discuss the Auranet, our implementation of a wearable community based on social space. Throughout the paper we maintain a strong focus on trust as a key element in supporting sociability.

1.1 Scenarios

To illustrate a wearable community in action and how wearable encounters in a ubiquitous computing environment can be augmented with the Auranet we have adapted part of a pre-existing scenario "Alice's Day Off" from [1]. We present a section of Alice's Day Off first as originally presented in [1], then a modified version "Alice's Day Off in a Wearable Community."

1.1.1 Alice's Day Off

"Alice pours some cold cereal, notices that she is low on soy milk, and walks into the living room. As Alice sits down at the couch with her cereal, the living room's wall display comes to life with the information that was previously on the kitchen display. "Reminder," Alice says. The wall display changes to show a list of to-do items. "Next time I'm near a grocery store, remind me to buy soy milk." A new reminder is added to the list. The text reads: "Proximity reminder, location grocery store, action message: buy soy milk -- confirm?" "Confirmed," Alice says.

Later that day as Alice is walking to the park, she runs into Charles, an old client of hers. After talking for a little while, Alice's wearable alerts her that there is a reminder associated with this situation by displaying an icon on her integrated glasses display. Without pausing in the conversation she touches the wearable to request the information. The text "swimming pool" appears in place of the icon. "Oh," Alice says, "Did you ever resolve the dispute with your contractor about the swimming pool?"

As Alice walks home that evening she passes through Garibaldi Square, near a Wordsworth store. One of Alice's shopping applications notices that Le Corbusier's "Toward a New Architecture," a book she is looking for, is listed as being on sale in Wordsworth for a lower price than it can be found on the net. She stops in the store and picks up the book. While she is there her wearable automatically discovers an available wall display and she uses it to call up a list of other books she is interested in to check the stores prices. Alice purchases her books by authorizing her shopping agent to transfer cybercash funds to the store, and walks out with a friendly wave to the cashier."

1.1.2 Alice's Day Off in a Wearable Community

"Alice pours some cold cereal, notices that she is low on soy milk, and walks into the living room. As Alice sits down at the couch with her cereal, the living room's wall display comes to life with the information that was previously on the kitchen display. "Reminder," Alice says. The wall display changes to show a list of to-do items. "Next time I'm near a grocery store, remind me to buy soy milk." A new reminder is added to the list. The text reads: "Proximity reminder, location grocery store, action message: buy soy milk -- confirm?" "Confirmed," Alice says.

On her way out of her apartment complex, Alice walks by her downstairs neighbor Daisy. As they pass each other in the hallway Alice and Daisy's wearables run the WALID Auranet task-trading application [4]. WALID is a program we have developed to analyze a users to-do list and compare the tasks with the to-do list of others who are in physical proximity. When it finds redundancy it will negotiate a trade that is optimal for both parties.

Later that day as Alice is walking through the park, many other Auranet users pass into and out of her *aura*. Alice's wearable knows she doesn't like to be disturbed during her morning constitutional, so it handles what tasks it can, without requiring Alice's attention. One of these tasks includes informing her friends in the park (through the Auranet *MoodMinder* application) that Alice would prefer not to be disturbed. After a while she sits at a park bench and decides she wants to have someone to talk to. She then runs *FriendFinder,* a proposed Auranet peer to peer application. *FriendFinder* looks for friends starting with her immediate *aura*, and then spirals outward next checking those people's Auras and so on, until she finds that Charles, an old client of hers, is nearby and available for a conversation.

Alice messages Charles using *AuraSMS* to let him know she would like some company. He uses *AuraFinder* to guide him to her bench where they have a nice chat. While talking, Alice's wearable alerts her that there is a reminder associated with this situation by displaying an icon on her integrated glasses display. Without pausing in the conversation she touches the wearable to request the information. The text "swimming pool" appears in place of the icon. "Oh," Alice says, "Did you ever resolve the dispute with your contractor about the swimming pool?" Charles says, "No, he never could complete the job; however, I've been gathering reputation information from the neighborhood [using the Auranet decentralized reputation application, *DIOGENES,* which we have implemented and described in [2]] and everyone's told me about this great pool man Eugene. I see that you really liked his work too."

As Alice walks home that evening her scheduled route passes through Garibaldi Square, near a Wordsworth store. One of Alice's shopping applications notices that Le Corbusier's "Toward a New Architecture," a book she is looking for, is listed as being on sale in Wordsworth. As Alice is an avid book buyer but never buys music she has configured her Auranet *CouponTrader* application to automatically trade away any record coupons she has for book coupons (using a system similar to that described in [3]. At some point during the day she traded to a passer-by a coupon pushed to her wearable from Feltin's CDs & Tapes for a 10% off coupon at Wordsworth. This exchange occurred automatically and without interrupting Alice. With the coupon, Le Corbusier's "Toward a New Architecture," is at a lower price than it can be found on the net.

Alice stops in Wordsworth's and picks up "Toward a New Architecture". Her wearable also signals a proximity reminder to pick up a copy of "WWF Superstars" for her downstairs neighbor, Daisy. Alice purchases her books by authorizing her shopping agent to transfer cyber cash funds to the store. Alice walks out with a friendly wave to the cashier.

When she stops by her neighbor's to drop off the WWF Superstars book, Daisy gives Alice a container of soy milk she picked up while at the market. This task exchange was made possible through the task sharing optimization done by the WALID agents earlier that morning.

By being in a wearable community Alice derived the following benefits that would not normally have occurred in a wearable and ubiquitous computing environment:

- Direct social cues sent to her neighbors via *MoodMinder*.
- Social interaction facilitated by *FriendFinder*.
- Face-to-Face interaction arranged by *AuraFinder*.
- Personal recommendations from her community acquired from *DIOGENES*.
- No cognitive load trading with strangers using *CouponTrader*.
- Task Sharing with a neighbor , *WALID*.

2 WEARABLE COMMUNITIES

In [4] we present the notion of a *wearable community,* designed to support a large group of users cooperating in their daily lives. It's easy to see what a wearable community is not. Although thousands of personal agents are communicating for the wearable user at any given moment, a wearable community is not a strictly agent community like the internet or various virtual meeting grounds. Nor is a wearable community simply a traditional community whose members own wearable computers.

A wearable community is a voluntary co-mingling of people and their personal agents, each community member acting in his/her own best interest and, if the community is properly designed, the interests of the community as well. Members of a wearable community communicate with each other through an assortment of wireless systems including cell, infrared and short range RF among others.

Wearable community members are physically mobile, with their surrounding environments affecting their communications. As the surrounding environment changes so will the optimal and possible communication channels. This changing environment mandates ad hoc networking as the community member moves through his or her day. For similar reasons these networks are almost by definition peer to peer, as there is never a guarantee that a service will be available that isn't self-provided by the community member.

Communities are about sociability. As described in [6] a computer network connecting people is also a social network. The benefits accrued from a wearable community arise from the resources made available from this social network. Our approach is directed towards developing technology that supports a wearable community by strengthening and augmenting the social interaction among the wearable community members.

By designing for communities of wearable users, pre-existing applications can be improved. We consider it very important when developing wearable applications to consider the community. In the scenario presented Alice uses two traditional applications, the "to-do list" and "e-coupons", both of which have been augmented through interactions with other community members. Currently we are continuing to develop applications that consider communities of wearables and we are in the process of developing a calendar application that will reorganize (where possible), planned events so that serendipitous meeting with friends and co-workers will no longer be left up to chance.

2.1 Trust in Wearable Communities

Human communities are based on trust. Trust is integral to every interaction, in every encounter, in every community. Every day we trust people to be who they claim, we trust what they say, and we even trust people to take actions in the distant future with no assurances other than their word. Without trust, cooperation would be impossible. [7] [8]

Trust provides people with a mechanism to handle an uncertain world. Trust simplifies our decision making process and allows us to quickly make a decision. Although trust does not allow us to know with 100% certainty that our interaction will be as expected, it does provide us with a mechanism for evaluating that risk. Once we understand the risk we can then evaluate if the benefits of our negotiations are worth the risk assumed. [9]

Agent communities can also benefit from trust to support negotiation and cooperation. [7] [10] Many mechanisms for supporting trust in virtual communities have been suggested and implemented, for example the PGP Web of Trust [11] and reputation models such as that described in [10].

Current agent based communities are attempting to implement these trust mechanisms. One example is OpenPrivacy.org's Talon system that provides a general reputation exchange mechanism. [12] Also, [13] describes how one can use hard security techniques to leverage information from an agent communities' "Web of Trust" into a traditional human trust mechanism.

Wearable communities do not function as either a traditional human society or an agent based community. However, as with human and electronic communities wearable communities can be greatly enhanced through the use of a trust mechanism.

In [2] we describe a distributed trust application with unique properties that utilize the advantages of a wearable

community containing both agents and a physical human presence. From the cited literature on trust we feel we can make the following statements about trust as it is applied in a wearable community:

- Trust of any entity in a wearable community will vary depending on who is doing the trusting.
- Trust can be enhanced through various mechanisms and actions including (but not limited to) past history, signed certificates, specific actions, and reputation information.
- Trust can be quantified, and its value can be used by members of a wearable community to estimate risk.
- Trust is specific to a domain and there are an unlimited number of domains to which trust might be applied. For example, I might trust you to deliver a package but not to fix my car.

3 AURANET

The *Auranet* is a network for communication in the social space[5]. The social space is that 12 foot radius[1] that extends around us in all directions and defines the space in which we as humans interact. In the Auranet we gain a contextual understanding of nearness. Any person, device or community member that is said to be "in one's Auranet" is also an object that is known to be nearby. With few exceptions that object is close enough that a human can comfortably interact with it.

The Auranet is the space in which encounters occur in our implementation of a wearable community. The Auranet is not the only space in which wearable community interactions can or should occur, but we have chosen it as a starting point. We have chosen social space for our implementation due to its significance in human social behavior. Social space is where people interact with friends and strangers. As one of the primary goals of our research is to augment social interactions, the 12' social space seems to be the reasonable choice. Every member of a wearable community has his/her own Auranet much like every company has its own intranet and every person has his or her own social space. Sociability encounters occur when two members of a wearable community are in each other's Auranets.

The Auranet's integration of the current physical space and social space with the electronic agent network allows personal agents[4] to make assumptions and take actions they could not do outside the Auranet. Personal agents can request that the user hand a physical object to another user. They can suggest that a conversation be started. They can even have a basis for speculation on relationships from repeated proximity.

This aggregation and mapping can be best visualized as an *aura*. The dictionary definition of an aura is: "an energy field that is held to emanate from a living being"[14] and in the Auranet all members in a wearable community emanate such an aura.

3.1 Encounters

A primary focus of our research into wearable communities is finding the answer to the question, "What happens when two members of a wearable community come face to face that doesn't happen when two people in a human community come face to face?" To answer this question, we first attempted to develop wearable agent applications. These applications showed that certain types of sociability enhancing encounters could occur and probably should occur but did not answer the broader question.

In our current understanding, there is a virtually unlimited number of personal agents and wearable community applications that can be unleashed. They will be based on the needs of the individual and of the community. In the following sections we describe a series of operations that we use to form our framework for encounters in a Wearable Community.

3.2 A Trust based Framework for Face-to-Face Encounters

A face-to-face encounter occurs in the Auranet when two members are each inside the other's aura. In other words, both parties are within 12 feet of each other. When this occurs the members of the wearable community may begin interacting either on a social level, an agent level or both.

We are not going to discuss the mechanisms for establishing and maintaining a connection either on the human or the agent level. Both are covered in depth in the appropriate fields' literatures. Nor will we discuss the hard security details of identity verification and certification. However, our framework does outline how agents can make progress communicating and cooperating with a reasonable expectation of benefit and personal security.

The system we propose assumes that an internal trust system is running on every community member's wearable.

[1] 12 feet is the standard approximation used in Sociology. The exact range varies between individuals and is very dependent on cultural factors.

It need not be the one referenced here nor must it base its decisions on the same or even remotely similar criteria. As wearable agents are customized, it is likely the internal trust application will be customized as well. So, in addition to having unique inputs (nurture), no two trust applications necessarily have the same methods of evaluation (nature). Mother Teresa is likely to have a vastly different trust evaluation mechanism than a graduate student in an inner city.

To function under this framework the only requirement is that a trust system exists and that it can return a trust evaluation that is understood by the local application calling the trust system. We assume for our example a trust system similar to that described in [2]. This trust system is domain specific with each application calling the trust system representing a domain (task-trading, roadside assistance, plumbing advice etc.) The trust system responds with a numerical value from 2.0 to -2.0 (best to worst) as a metric for trustworthiness in the domain specified by the requester.

Applications in a Wearable Community are either communicating or negotiating over a specific domain. By dividing trust into domains it is possible to be able to handle multivariate trust issues, like trusting someone to drive you to the airport but not trusting them to fly the plane. Wearable agents interact over these domains using games theoretical techniques but are often at a significant disadvantage if they propose or reveal information first. [15] [3] But, negotiation and cooperation is not possible without one of the Wearable agents revealing some information first. The information to be revealed must be based on the trust valuation the agent places on its negotiating partner as there is no other metric on which to base such a decision. If the trust value that exists is of a higher level than the information that is desired - either as a proposal or in response to a query - then it is revealed.

We have categorized information to be disclosed into three general categories; however, a domain may have more or fewer categories depending on need. In the general case these categories are: public, semi-private and private. Each category fully entails trust for all lower categories.

Applications in wearable communities will run to the extent allowed by their trust values. So, if the trust level allowed for a user in an application is semi-private all information & cooperation that is possible at a semi-private or public level will be available. This does require the application to be designed such that program flow acts in increasing trust order.

It is important to note that a level of trust is required even to reply to a query which asks if an application is running, much less what data might be available or to cooperate over the domain. For example, you may not want to tell everyone that you are running a dating or music swapping application. Also, it is possible that an agent might freely share that a music swapping application (public) is running but which music is available might be set as public, semi-private, or private. The application may also be designed to respond with certain pieces for public access and more at semi-private or private.

For example, a threshold for releasing private information may be at 2.0 (the maximum) although public information might be released at a trust valuation of 0.0 (no information.) To put this into even more concrete terms using the task trading application from [4] we see the following:

An encounter occurs in the Auranet between two task trading applications. Alice's wearable agent asks Bob's agent what tasks Bob needs to do. Bob has several tasks including dropping off a book at the library (public) and picking up medical records (private). Bob is willing to share the information that he needs to drop off a book at the library with anyone who doesn't have a "bad" (less than 0.0) reputation in the task trading domain, but he is only willing to discuss picking up his medical records with people he completely trusts.

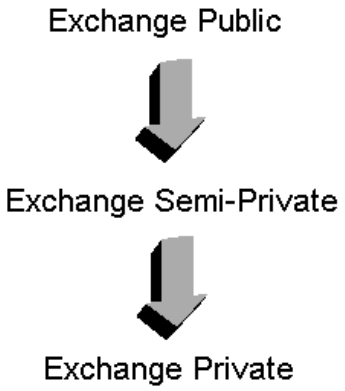

Figure 1: Single Application, Flow by Trust Level

3.3 Framework for Multiple Agents

The framework becomes more complicated when multiple wearable agents are involved since the trust value for one domain could be modified by actions taken in another domain. For example, Bob asks Alice if she's running the music swapping application. Alice's wearable agent checks her local trust server and Bob has a value 0.5 in the music swapping domain. Alice's threshold is set at 1.0 (semi-private) before she will reveal that she is running a music swapping application. As Bob is not trustworthy enough based on the information supplied by her local trust server she will not reveal that she is running a music swapping application.

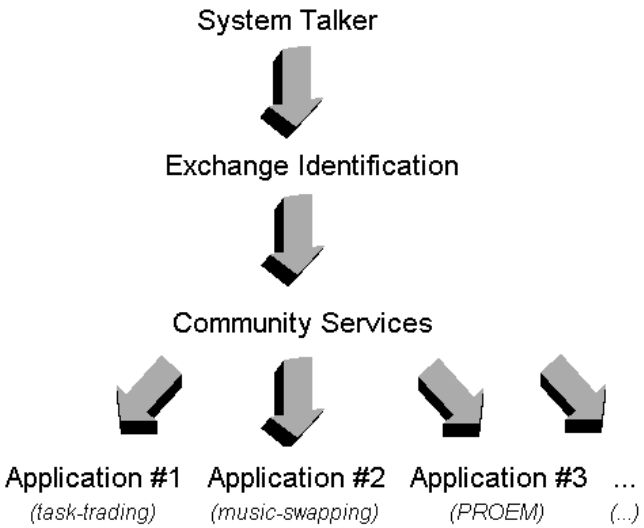

Figure 2: Multi-Agent Encounter Framework

However, when Alice's wearable agent queries Bob's agent to see if he's running a video swapping application, Bob's wearable agent responds positively. In addition to furthering the exchange of public domain video, Alice could have her local trust application increase the value in the music domain to 1.0 of anyone with whom she's successfully exchanged video with. She should now be able to inform Bob that she is running a music swapping application.

This can be accomplished by using a thread-like model for the encounter. In the first part of the encounter, the basic acts of establishing communication and identification occur. If these steps are not successfully negotiated then the encounter ends. This first phase is the *system talker* stage, where the communications parameters are established. This stage is followed by the *identification exchange* stage where cryptologically signed identification information is passed between the parties in the encounter. The encounter will also end if either of these stages is not successfully completed.

The next step in the encounter is the *community services* stage. Direct negotiation between the parties involved still has not occurred, but now, support services that all members of the community provide, transact. These services are defined as being unambiguously beneficial to every member of the community and lay no onus on the transacting parties. An example of an Auranet community service is passing along Auranet e-mail packets.

After this phase completes either or both members can start activating wearable agents to run Auranet applications. Each application may result in a successful negotiation/cooperation or in the determination that no cooperation is possible in that application's domain. An application may also be left open if it's possible that changing circumstances may allow further activity. For example, if trust values change favorably as a result of other agents' interactions, communications may then proceed. This can be seen in the above example with Alice and Bob. As additional trust is established Alice can inform Bob that she is running a music swapping application and the communication can proceed.

The encounter ends either when there are no wearable agents with further open communications or when all active agents are left open but still delayed.

4 APPARATUS

Wearable communities are designed to be hardware independent. Any device that can use MANET RF is a potential candidate. With the strong support of industry the BlueTooth standard will likely become an ideal development platform for a wearable community.

However, there are both implementation problems and design flaws with the proposed BlueTooth standard. In time it is likely these issues will be worked out and a fully functional multi-platform wearable community will be implemented under this standard.

Figure 3: Cybiko Intertainment Systems.
Right: Default Cybiko Configuration.
Left: Back of Auranet Enhanced Cybiko
Top: Front of Auranet Enhanced Cybiko.

Until Bluetooth becomes an acceptable standard we are primarily developing our wearable community implementation using Cybiko[16] Intertainment Systems. Cybikos are 32 bit PDA devices with built-in RF networking in the 902-928 MHZ range. They are also equipped with an RS232 port and an expansion slot. Input to the Cybiko is done through a thumb pad and a small QWERTY keyboard. Currently we are developing under Cybiko's proprietary Cy-OS (ver 1.2x) and the Cybiko Software Development Kit supported by our own custom extensions to provide a near ANSI C environment.

To support our work in wearable communities we have modified the Cybikos by encasing their back and sides in a heavy duty aluminum foil shell attached with Duck brand duct tape. The purpose of this modification is to reduce the range of the RF communication system. With the RF antenna retracted and the aluminum casing applied we have measured the maximum RF broadcast/reception range to be about 5 meters, down from the 50 meters that the default configuration provides.

6 BACKGROUND AND RELATED WORK

The concept of automating negotiations between agents goes back to some of the earliest works in computer science [17]. Since its inception in 1929 the *Journal of Social Psychology* has been publishing research on human groups and communities. It was not until fairly recently that the study of humans in electronic communities began. With the advent of USENET in the 1980's, electronic communities started to become a noticed and researched social issue. Rheingold's work with the WELL[18] is an example of significant early work in this area.

Liveware[19], another early project, is similar to an early wearable community. The authors proposed a social network facilitated by personal computers in which the users would transport information by physically exchanging floppy disks when encounters occurred. The users would then take the new information back to their personal computers and update their application data. They did stress the transmission independence of their system but their work ended before the technology had advanced to the point that portable computers were a viable option.

The Piconet project [20] in 1997 is an early RF ad hoc networking system supporting a full range of portable and embedded devices. This very promising work seems to have been subsumed into the Bluetooth project. Other researchers have developed devices that act as a single Auranet application, the most notable being the Meme Tags [21] and it's commercial descendant the Lovegetty.

Currently, there are many groups that are researching aspects of virtual and electronic communities. However, most of these communities lack the physical proximity component of a wearable community and the work is generally agent based as opposed to the agent and direct manipulation paradigm that we propose.

7 FURTHER WORK AND OUTLOOK

Communities, including wearable communities, are based on more than just face-to-face encounters. Hence, we intend to continue our research into how sociability in wearable groups can be helped to grow and mature. We are continuing to examine the social protocols that are needed and developing applications that are necessary to support these emerging communities.

Much as we hope to grow and mature our local wearable community, the technology and tools we use are growing and maturing as well. They will become more ubiquitous and robust and we hope to guide the development of these tools in a manner to promote community and sociability. We are currently developing a peer-to-peer platform that will support social growth not oppose it.

We have implemented many of the wearable community/Auranet applications used in these examples, including a task trading application, a trust system and a profile based introduction system. However, these applications have developed over time and many were developed either for the Handspring Visor, custom built RF equipment or for our wearable community simulator [2][4][22]. As we now have access to sufficient RF technology by way of the Cybikos an immediate priority is to bring these applications together onto a single platform. We will then attempt to determine what the core applications are for an Auranet based wearable community

We plan to expand our sociability into the Auranet. A high priority is to research strong and weak social ties and how they differ among traditional human, electronic, and wearable communities. We also intend to expand our research in wearable communities into other human spaces. We intend to examine how applications might work in closer proximities, personal space (1 to 3 feet) or intimate space (a few inches). Also, we intend to investigate the benefits of expanding one's aura into public space, which can go out to the range of the RF devices (50 meters).

We have only scratched the surface of the Auranet, with hundreds or thousands of Auranet applications waiting to be developed and tested. It seems there may be as many Auranet applications as there are ways of engaging in face-to-face communication, if not more! In the future people may use the Auranet coupled with augmented reality systems to view each other's Auras. Some might use their Auras as a means of expression, showing their moods or feelings. Auras might expand and contract depending on

how communicative or social a user is feeling and aura visualizations could show the spaces an Aura is "exploring". Auras could even be viewed shifting in size, shape and color. Exotic and colorful Auras could become fashion accessories for wearable community members or they might be tools that visualize another's reputation or social status.

As a tool for communication, negotiation, a means of expression, and more we see a broad horizon for the Auranet. It is one in which aura reading is not just in the realm of the metaphysics but that of the wearable user as well.

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