In Proc. of *1st International Workshop on Ubiquitous Systems for Supporting Social Interaction and Face-to-Face Communication in Public Spaces*, 5th Annual Conference on Ubiquitous Computing, October 12- 4, 2003, Seattle, WA, pp. 41-47

IntelliBadge™

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ABSTRACT
This paper describes the IntelliBadge™ project that uses RFID technology to track participants at public events and provide them with personalized, real-time, value-added, location-aware services. IntelliBadge™ was first publicly showcased at IEEE Supercomputing 2002 (SC2002), the world's premier supercomputing conference, in the Baltimore Convention Center, November 16-21, 2002. Volunteer participants were required to register in the project database and carry a smart tag. We developed a web-based application that registered participants could use to locate each other, search for events and places of interest, access real-time events attendance statistics, and estimate their mileage walked while being tracked. We also developed various interactive visualization applications that provided an overview of the on-going event activities and aggregate data about the conference attendance.

Keywords
Ubiquitous systems, RFID, information visualization

INTRODUCTION
The IntelliBadge™ project was initiated by the SC2002 Organizing Committee. The organizing committee's goals were to push the technological envelope at SC2002, to provide a fun and value-added experience for technical program attendees, and to collect data that could provide important, useful information to conference organizing committees. SC2002 Organizing Committee and NCSA decided to protect the privacy of participants, in that the attendees' data would not be distributed or sold, though NCSA could mine the post-conference data using aggregate, non-personal information. The committee and NCSA decided that participation of attendees would be voluntary. After some discussion, it was decided that the IntelliBadge™ registration process would not be integrated into the SC2002 registration. IntelliBadge™ required a separate, dependable and secure registration process. This decision presented more challenges for the project.

While the SC2002 committee had basic requirements for the project as stated above, the NCSA team took the creative and technical lead while embracing many unknowns and technical problems during the implementation of this experimental production. One of the biggest challenges was to find an appropriate type of tracking technology that would enable a conference participant to locate people at conference events. Other challenges included contractual negotiations with University of Illinois, IEEE, and the equipment vendor as well as managing numerous conference arrangements. The SC2002 committee provided a limited budget for the project and NCSA provided human resources. Given this arrangement, many issues of billing, intellectual property, and asset management needed to be negotiated before the project could proceed.

The SC2002 committee provided some basic guidance regarding the goals of this project. The NCSA team further specified the goals in terms of design, functionality and human experiences, considering attendees' behaviors, their responses, and their needs. The first important goal was to track volunteer participants in real-time during the conference and at event locations. Ease of use for the participants and the transparency of the underlying technology were concomitant goals. Participants would have to carry a smart tag with them at the conference, and we considered smart tag size and probability of losing or forgetting. The convenience and security of the IntelliBadge™ registration drove the design of the process and software. Convenience of registration and privacy were in direct conflict with another important goal to get as much relevant information about the participants as possible in order to provide data for the statistics and visualizations. We preferred to get a richer database, but decided it was more important to make the process user friendly.

The second important goal was to enable attendees to conveniently access services within a secure environment. The first iteration at designing access to services required participants to go to kiosks that would be conveniently located at the conference site. Eventually, we decided to build a web application in addition to the kiosk to provide more convenient access to services via the Web. The most

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important services included finding people and events; the goal to provide participants with useful information drove these decisions.

The third important goal was to provide visualization displays showing conference data. We determined that no personal information would be shown on these public displays; rather we would visualize general aggregate data. The first pass at specifying real-time visualizations included a plan to use plasma panel displays. We decided to provide multiple larger-scale visualization displays for attendees to view in addition to the plasma panel displays.

The NCSA team participated in many pre-conference brainstorming sessions that resulted in ideas for games, interactive events, and additional interest profiles; however, the deadline constraint precluded many interesting ideas. The web application, visualizations, registration booth, and conference signage provided information avenues to participants and spectators. As the project evolved, it was apparent that this technological fusion is evolving into a community building tool and could connect people in novel ways.

RELATED WORK

CharmBadge by Charmed Technology, Inc. [1] uses IR-based tags programmed with attendees' individual business card information. This information is exchanged between attendees as they interact with each other and the interaction is logged and subsequently uploaded to a private website accessible by each user. The system does not provide data to the users in real-time and does not track events attendance.

nTag by nTAG Interactive, LLC [2] uses semi-passive Radio Frequency IDentification (RFID) tag operating in the UHF band which enables a conference organizer to use it for security, to record how many people attended certain sessions, or to track how many people visited certain areas on the exposition floor. When people meet, their tags exchange (via IR) information about their interests and preferences, thus facilitating social interaction among the attendees. Tags also store and provide convenient access to the conference program.

SpotMe system by Shockfish SA [3] requires participants to carry a cell phone-size device via which they can find out who is standing within a 30 meter radius. Participants can be notified if a person with shared interests comes within 10 meters, and they can send messages to each other or exchange electronic business cards. SpotMe does not provide services based on the knowledge of who attended what events.

IntelliBadge™ differs from the above-described systems both in terms of the core technology used to track people and in terms of the end-user applications. It implements location tracking by proximity to RF location markers installed at the points of interest. All the user services are built around tracked location information and a priori knowledge about the attendees and the conference events.

SYSTEM OVERVIEW

Two major driving forces influenced the project implementation: budget and time. To our knowledge, this type of integrated system of tracking technology, backend services, web application, and real-time visualizations for a conference production had never been realized. Many technical and logistical problems needed to be solved.

We conducted a study to identify the most appropriate technology that would allow us to achieve our first goal: to track participants in real-time as they attend various conference events. We quickly realized that the most promising direction was to use RFID technology. Although this technology generally is not used to track people and has numerous limitations, it was found that some of the modern commercial implementations could be tailored for our application. We conducted a formal evaluation of several such systems and decided that Savi Series 600 RFID System made by Savi Technologies, Inc. [4] was appropriate and economical for the project.

The tracking equipment budget restricted the number of people and locations to be tracked. Tracking was limited to Technical Program attendees and a subset of the locations for the Technical Program. Unfortunately we could not track tutorials, panels or educational program. We could afford to purchase enough Savi equipment to reliably track four rooms on the 3rd floor where technical lectures were given, the Ballroom on the 4th floor where keynote and plenary sessions were given, and Exhibit area on the 1st floor of the Convention Center (Figure 1). Tracking outside of these main locations was desirable, but not necessary for delivering the required services. It was not necessary to provide the absolute locations of each attendee, instead we could track whether the participant was in a room and this information would be sufficient.

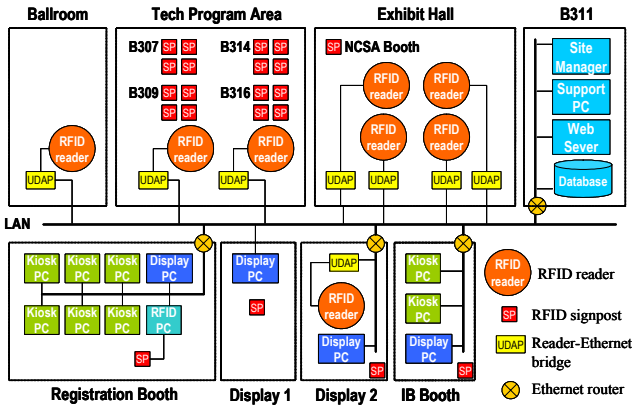

Figure 1. IntelliBadge™ equipment deployment in the Baltimore Convention Center.

Participants received an RFID tag to carry during the conference that cost approximately $20.00. We wanted to

retrieve these tags after the conference. Therefore, we designed prize schemes to provide incentives to participate and return the badges.

The second major goal to provide services to attendees was implemented by first setting up a secure system for participants to input and retrieve information (Figure 2). We attempted to simplify the IntelliBadge™ registration process by reducing the amount of typing and enabling a person to scan his/her SC2002 registration badge instead of typing details into the user profile. Each participant could opt to reveal or not reveal personal information by checking a box. We decided that reducing the number of professional categories might help this process and would enable better visualizations. User and professional interest profiles were designed to take less than one minute to complete. Once the participant was registered, he/she could access and edit his/her information conveniently. If participants forgot their password, they had to go to IntelliBadge™ registration area and provide their personalized security question to IntelliBadge™ staff.

We implemented and made available the primary services to IntelliBadge™ participants only: to find people by names, categories, professional interests, and groups and to find events of interest. We enabled people to define unique group names and find people by groups. Current events could be sorted by name, time, and location. Calculating mileage was included as fun-factor.

Secondary services were provided to any attendee or spectator that went to the IntelliBadge™ web application. Any conference attendee could access the restaurant guide and map without being an IntelliBadge™ participant. He/she could select restaurant by food type, and sort by name, proximity to convention center, and cost. Any attendee could access relevant information about the project, prizes, legal issues, health concerns, puzzles, behind-the-scenes staff, and sponsorship.

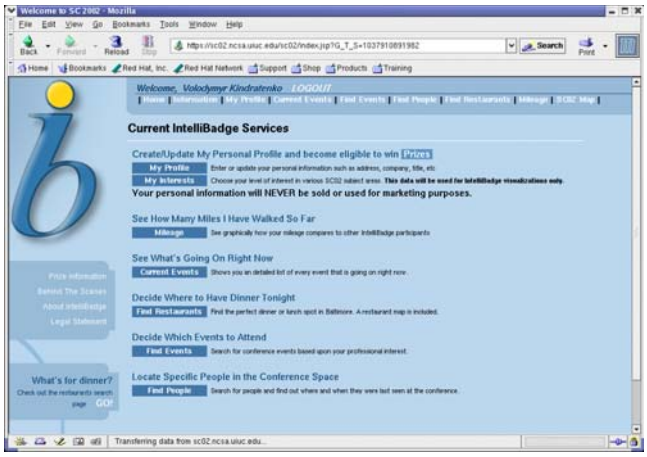

Figure 2. Web kiosk application index page.

In order to achieve the third major goal – visualizing the conference – we decided to build multiple visualization schemas and embed them in a main application that provided the timing control and switching between visualizations. This approach was strategic to enable visualization programmers and designers to work independently and later integrate visualizations.

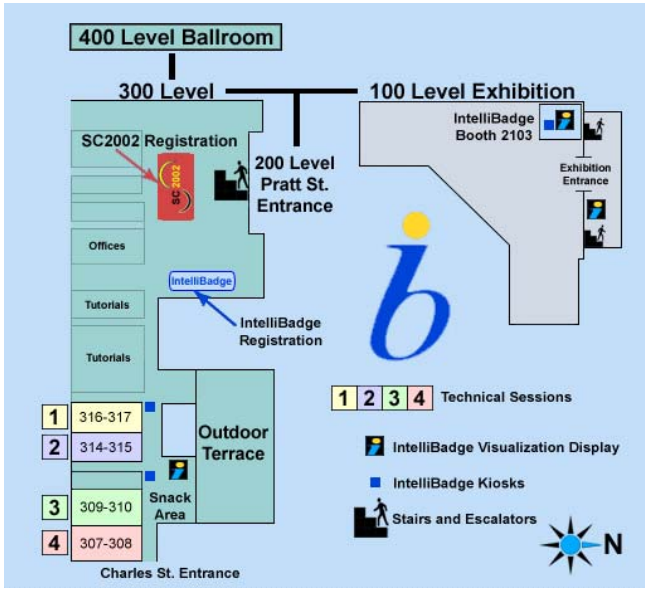

Figure 3. IntelliBadge™ SC2002 map.

The designers provided layouts, maps, and logo styles that were consistent with the kiosk/web application. We developed an abstract map (Figure 3) to help attendees easily locate tracked areas and key IntelliBadge™ sites at the Convention center and used this map consistently throughout IntelliBadge™ literature, visualizations, and web application. The map correlated locations to changing Technical Program events.

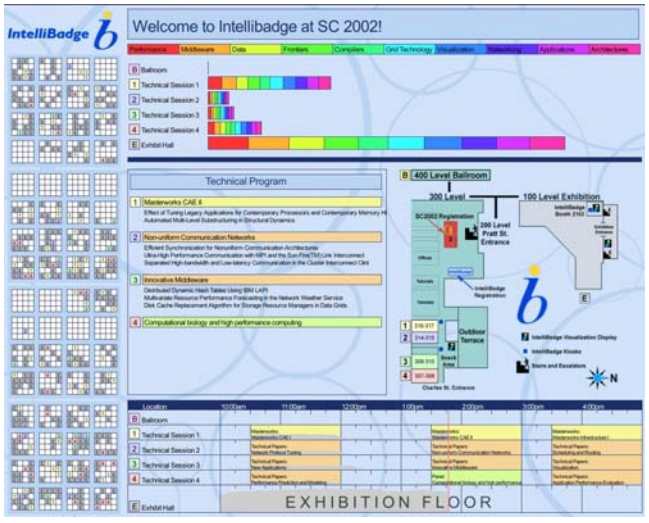

Figure 4. "Conference at a glance" visualization schema.

The basic visualization schema 1 (Figure 4) primarily focused on two-dimensional statistical displays and provides people with a "conference at a glance" overview. An Interest Profile bar graph at the top of the screen showed relative numbers of people from each interest category at each current event. Messages scrolled at the top of the screen and a dynamic timeline scrolled at the bottom. A State Table (Matrix) on the left side provided a 'geek' puzzle element. The Matrix was dynamic and responded to IntelliBadge™ participants by placing a colored square on a unique location in the matrix when he/she approached a visualization display. This schema provided the most practical and traditional information visualization.

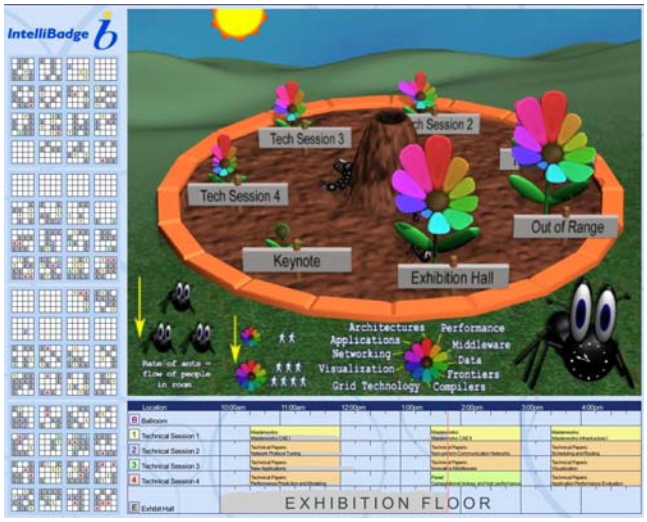

Figure 5. "How does you conference grow?" visualization schema.

To provide visual continuity, the above state table Matrix (left side) and Timeline (bottom) remained on the screen when switching to Visualization Schema 2, "How Does Your Conference Grow?" (Figure 5). The goal of this visualization was to provide a three dimensional poetic alternative to the two dimensional Interest Profile bar graph from Visualization Schema 1. A garden visual metaphor employed flowers as locations, colored petals as interest categories, and walking ants as rate of people walking through the tracked areas. This schema was designed to be fun and humorous. We developed a pre-conference playback of this visualization using simulated data; then we incorporated it into a plasma panel slide show describing how the RFID technology worked and explaining the various visualization schemas. This slide show played continuously at the IntelliBadge™ registration area and was useful to communicate complex information about the project. The garden metaphor playback was designed to capture peoples' attention and bring humor to what was often viewed as a 'big brother' project.

Visualization schema 3 (Figure 6) retained the conference timeline when switching to an interactive, global map with dynamic camera. When participants moved near the visualization displays, a dynamic smart camera moved to the place of origin of the participant, if he/she had chosen to reveal this information in his/her user profile. A blowing flag marked the place of origin and text would reveal the name of his/her home institution. Each of the three visualization displays had a video camera streaming images of viewers in front of the visualization display, and these video windows correlated to the Responsive Map. This design visually mapped the people in the video screens to their locations of origins on the Responsive Map with the color of a flag that corresponded to the color of the border of the video window. As people approached the three displays, the Map responded to all of them in order. The goal here was to create a sense of community at the conference and provide interesting people interactions.

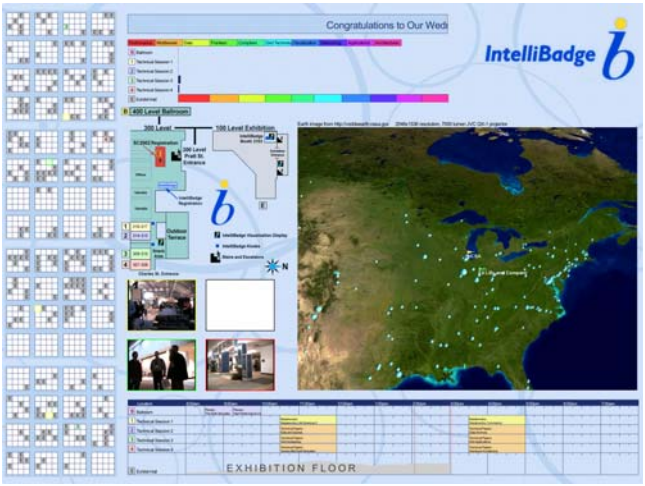

Figure 6. Interactive visualization schema.

We considered how people would respond to being tracked and designed visuals, literature, and signage to anticipate their responses and encourage participation. We strategically negotiated the location of the IntelliBadge™ registration and visualization displays for the conference to get maximum visual exposure. One of our biggest concerns before the conference was that people would not want to be tracked, that they would not trust the situation, and that they simply would not volunteer to participate. We used the web application, visualizations, handouts and signage to provide as much information as possible in advance and during the conference to alleviate such fears.

THE CONFERENCE

Setup for the conference began November 11 at the Convention site in Baltimore. While the Convention site had been tested with a small number of units of Savi hardware during the Summer 2002, the large integrated system and production environment had never been tested before the conference. NCSA staff had developed and tested pre-conference with a limited number of Savi

equipment in the Beckman Institute and with simulated data; it was not possible to test the real-world scenario until all of the equipment was installed at the Convention site. The most serious and challenging technical problem was discovered a few days before tracking would begin. This problem related to compatibility issues between Savi hardware and the network at the Convention center. SCInet, Savi engineers, and NCSA staff worked together to solve this problem, otherwise tracking would not have been possible for the Exhibit Hall. The result was that the ballroom tracking was set up later than anticipated.

IntelliBadge™ registration began at noon on November 16. We strategically planned that IntelliBadge™ registration would be proximate to the SC2002 registration in the Baltimore Convention Center. During the conference, NCSA and SC2002 student volunteers staffed the IntelliBadge™ Registration Booth where six kiosks were located. The first day of registration, we actively encouraged IntelliBadge™ registration and worked to get the attention of attendees. We staffed the registration area to assist registrants through the process. Even though the IntelliBadge™ registration had been designed to be easy, we attempted to walk people through the process if possible. We discovered that scanning the SC2002 badge was more difficult than expected for most people. Often registrants needed assistance with this process. Registration was intense but ran smoothly with only a few minor glitches.

Participants displayed interesting behavior during the registration. They loved to create groups and get people to join those groups. Thus, an unexpected by-product of being able to create a group was the fact that people would solicit their friends to join IntelliBadge™. The technical program ran from November 19-21 and we had planned to track people during this time. Participants did not understand this right away and wanted to find people immediately. The killer application turned out to be mileage calculation: people were very competitive and wanted to know how many miles they walked during the conference as compared to others. Some participants were quite unhappy if the mileage did not reflect their perceptions. Many participants returned to registration kiosks repeatedly to find out how many miles they had walked.

Most of the SC2002 committee members and NCSA staff could only guess how many people would participate, and they anticipated that only a couple hundred would volunteer. During the registration and with all printed material, NCSA staff impressed upon attendees that this was an academic experiment sponsored by IEEE and that the collected registration data would be protected from distribution. We ended registration after dispensing approximately 900 IntelliBadge™ tags. From this point of view and the unanticipated level of participation, IntelliBadge™ was declared a success by many SC2002 committee members.

Rear-screen projection systems were located at three sites in the Conference. The visualization display located in the Technical Session area across from room 315 and the display located at the entry to the Exhibition used 1280x1024 resolution projectors donated by JVC. JVC also donated 2048x1536, 7000 lumen projector that had an amazingly bright image with high resolution where we could show the most information simultaneously. JVC sent two employees to setup the three projectors. During the conference, NCSA and JVC personnel staffed the IntelliBadge™ Exhibit Booth 2103 in the Exhibition Hall.

The visualization applications were mostly up and running by Monday evening Nov 18th during the Exhibit Hall opening. Due to an unexpected event, the Responsive Map was delayed in getting operational. Likewise, the garden metaphor visualization had problems running in real-time. However, by Wednesday, most of the visualizations were working well and providing information to the attendees.

The Technical Program area and IntelliBadge™ Exhibit Booth received the most attendee traffic. The Responsive Map Visualization Schema 3 provided a kind of cocktail party atmosphere where people gathered, and people locating one another on the map encouraged casual conversation. Several participants met one another when their country of origin was displayed and they discovered others of like origin.

POST-CONFERENCE DATA ANALYSIS

SC2002 conference attracted 7,240 participants with 2,188 paid technical program registrants eligible to participate in the IntelliBadge™ project. In total, 900 RFID tags were given away resulting in 890 registered participants. The remaining 10 tags apparently were given to the participants who never registered to participate in the IntelliBadge™ project. In addition, 18 participants newer brought their tags to the Convention Center during the Tuesday-Thursday conference events. Thus, only 872 (40% of paid technical program registrants) were tracked at the conference.

On Tuesday Nov 19th only 857 tags were present in the Convention Center, on Wednesday Nov 20th only 752 tags were present, and on Thursday 21st only 677 tags were present. This is probably because some participants returned their tags before the end of the conference, as early as Tuesday morning, and also some participants could have forgotten to carry their tags.

In total, 752 tags were returned by the end of the conference: 69 tags were returned by the end of Tuesday, 69 tags were returned on Wednesday, 470 tags were returned on Thursday, and the remaining 144 tags were returned on Friday.

From the time registration began (10:00am on Saturday, Nov 16th) to the time web server was shut down (11:00am on Friday, November 22nd) registered users logged into

IntelliBadge™ Kiosks 1771 times on-site and 1370 times remotely. Registered users logged in IntelliBadge™ kiosks on-site on average 2.2 times: 529 users used kiosks at least once, 34 users used it at least 10 times, and 8 users used kiosks at least 20 times, 361 users (41% of all registered users) newer used kiosks after the registration.

On average, a user spent 3 minutes 38 seconds filling in the registration profile, an average on-site kiosk session lasted 1 minute 53 seconds, and the total time spent by all users using the kiosks (excluding the registration time) was 83 hours 7 minutes.

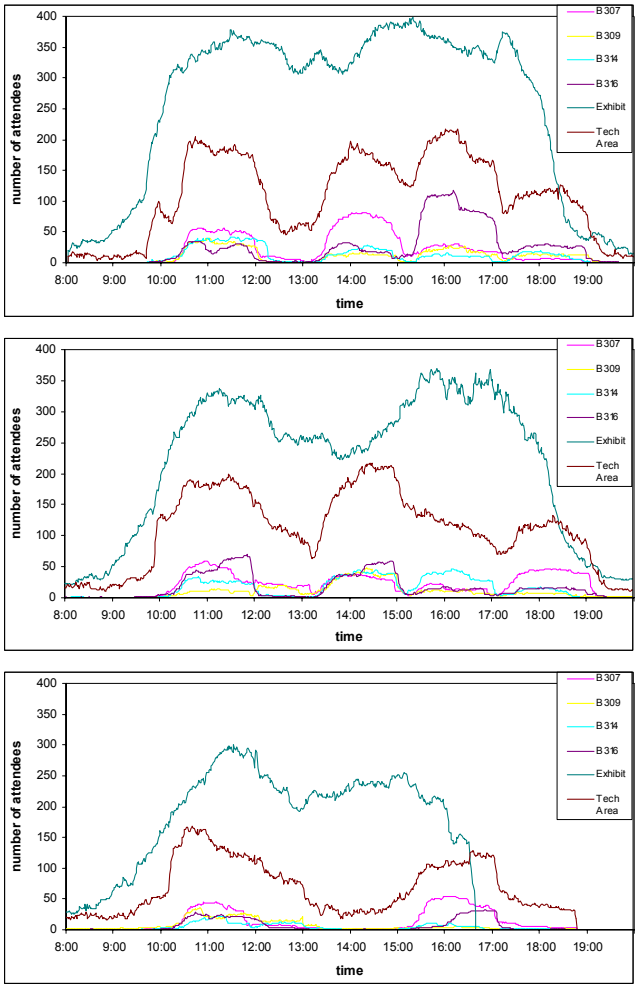

Figure 7. Events attendance charts for Tuesday, Wednesday, and Thursday.

We consider a display to be used if a person spent at least 1 minute and no more than 1 hour in front of it. Based on this, the display located on 300 level was used 209 times, the display at the exhibit hall entrance was used 37 times, and the display in the exhibit floor booth was used 206 times. All together 3 displays were used 452 times. An average display usage session continued for 3 minutes 35 seconds combined for all 3 displays. An average display usage session for the display in the Technical Program area was 3 minutes 7 seconds, for the display at the Exhibit Floor entrance was 2 minutes 22 seconds, and for the display in the Exhibit Floor booth was 4 minutes 17 seconds.

On average, attendees spent 7 hours 55 minutes on the exhibit floor, 3 hours 58 minutes in the technical program area, and 2 hours 27 minutes attending technical program events. Out of 890 IntelliBadge™ participants only 592 attended Technical Program sessions. On average, each conference participant attended 3.6 sessions. Figure 7 shows various locations/events attendance for 3 days of the conference.

The maximum distance walked during Tuesday-Thursday was 43.5 miles, while the average distance was about 6.9 miles. The lowest mileage logged was 0.05 mile. The extreme lows were probably caused by participants who forgot to wear their badges for most of the conference and by those who spent a lot of times in areas not covered by the readers. The extreme highs were probably influenced by overlapping readers.

LESSONS LEARNED

The Savi Technology Reader has a specified maximum receiver range of 300 feet. At the Baltimore Convention Center, tags on the convention exhibit floor were able to routinely transmit successfully to more than one reader at that distance. This reader over-coverage of the conference led to an unexpectedly high number of near-duplicate entries in the database. The problem is further complicated by the cross-floor reader coverage: it is difficult to tell upon which floor a tag was located without line-by-line human interpretation of the near-duplicate database records.

We did have a spare for the Savi Site Manager embedded Windows NT machine, but it was not kept powered on and ready for immediate use. As an apparent causal result, the site manager was the only machine to crash during the conference, and it took 10 minutes to get its replacement configured and running. During those 10 minutes, the seven Savi Technology Readers continued to receive and store beacon and signpost events from all tags at the conference. The performance characteristics of the site manager are such that the readers in the most densely packed areas of the conference (i.e., the middle of the exhibit floor) fell roughly 2.5 hours behind with events that occurred after the site manager crashed. This led to an unexpected system behavior: if a tag with a display signpost (un)detect event happened to gets its information to a reader far away in a relatively unpopulated area of the conference, then the display responded within 3-5 seconds to that tag's presence. However, of a tag happened to get its (un)detect event information to a backlogged reader first, then a user's presence at a display might not appear until long after the person carrying the tag has left. On-site, we discussed the solution of causing the backlogged

readers to clear their buffers, but since this would cause difficulties for subsequent data mining activities, we chose to let the readers catch up without losing user tracking data.

We thoroughly tested various aspects of the IntelliBadge™ system at NCSA using the same equipment and a similar system architecture before deploying the system to Supercomputing 2002. Knowing that we needed to support network sub-netting at the conference, we set up the system to span two Class B subnets at NCSA. It turned out that our assumption that if Class B sub-netting worked, then classless IP addressing would also work was incorrect. The four Savi Technology exhibit hall readers, which were on a different subnet than the site manager, had a bug that prevented them from correctly utilizing their non-octet aligned netmask and routing to the site manager. Members of SCinet, the all-volunteer Scientific Computing Network group responsible for networking at Supercomputing 2002, fixed this problem for us by effectively putting all seven readers and the site manager on the same subnet. They did this by running the four exhibit hall readers through a virtual LAN.

Since we did not know exactly what sort of processing power that we needed for the Linux servers, we assumed that a Dual Pentium III Xeon 550MHz machine with fast SCSI drives and 1GByte of RAM would be more than adequate for each server. In practice, while the machines did hold up quite well, the average system loads (as given by uptime) were consistently in the range of 4-5 with occasional spikes up to a load of 7. Our experience is that consistently high system loads in this range can often lead to runaway system load conditions in which no useful work can be performed. Even though this meltdown did not happen, the observed average system load levels suggests that for more than 900 IntelliBadge™ users and 7 readers, we either require more servers for load balancing or higher performance servers.

ACKNOWLEDGMENTS

We would like to thank the SC2002 Organizing Committee, SCinet, and IEEE Computer Society for support of the project. In particular, we are grateful to Prof. Roscoe Giles (SC2002 Chair) and Prof. Daniel Reed (SC2002 Technical Program Chair) for their continuous support and encouragement.

Valuable contributions to the system design were made by Alex Betts (vMaya™ implementation), Robin Dhamankar (database and post-conference data analysis), Jon Dugan (network support), Alex Farthing (Windows support), Tony Kaap (how does your conference grow visualization schema), Gaurav Kalmady (database interface), Jackie Kern (on-site installation), Albert Khakshour (hardware deployment), Patty Kobel (administrative support), Lorne Leonard (graphics design), Stuart Levy (backend visualization services), James Long (IRIX support), John Martirano (streaming video and post-conference data analysis), Robert Patterson (interactive visualization schema), Mary Pietrowicz (RFID equipment evaluation and project planning), Chris Pond (web server), Jennifer Powell (hardware deployment, kiosk services, and on-site help), Paul Rajlich (visualization front-end implementation), Anna Rovedo (graphics design), Barry Sanders (graphics design and front-end web kiosk services), Michael Shapiro (back-end web kiosk services), Alan Shih (database and project planning), Steve Quinn (database), and David Wheeler (network and on-site installation).

We are thankful to Thomas Manzagol and Jack Cowardin from Savi Technology, Inc. for Savi's contribution. Some of the equipment was also donated by JVC and Freeman Decorating Company.

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