DynaSurface:A Framework for Device Notifications using Nano Coatings in Connected Devices

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***Abstract*— DynaSurface is color change notification framework in connected devices and accessories. In this framework, devices and accessories are connected using a physical connector or short range communication. Multiple devices are connected using a controller for home networks and intra-home networks. Devices and accessories are coated with nano paints. Coating is for full body or portion of body. With advances in nano technology, nano paints that change color on voltage change are available [1]. These paints change color in a color range when subjected to voltage change. Even though other materials can be used, nano paints achieve substantial savings in terms of BOM cost, memory, real-time response and power consumption, which can not be achieved with other materials discussed in the paper. Applications on device are capable of interacting with programmable paints using an API. In this paper, we present end to end components of the framework and how they interact in a network based on ambience inputs, which is substantiated using simulation results**

Keywords-Ambient notifications; nano paints; connected accessories; presence detection; user localization

I. INTRODUCTION

Casings of Consumer electronic (CE) devices are made using metal, rubber, silicon, leather, fiber and plastic materials. Color coatings on these casing are static in many cases and do not require memory, communication components and power to show or change color.

Sony Xperia introduced a mobile with detachable bottom cover to change color [5]. Problem with the covers is that they need to be physically changed and color change cannot be controlled by software.

Many device accessories have static colors; with some cases have detachable covers. Also color change cannot be controlled with software. Even though accessories are connected to device using short range communication (BT, Wifi, Physical connector, etc.), there is no control from device over accessory color change.

Devices are also connected in a home network using technologies like UPnP, DLNA. Latest versions of these home network technologies support remote connectivity of devices and intra-home networks using internet.

Ambient applications in a connected network takes placement, facing, presence and other factors which showing notifications. Source device is one which receives an event to trigger a notification. Destination device(s) are one or more connected devices to handle the notification. Decision on destination device sub-set from connected devices, is taken by a controller.

Fig. 1. UPnP based connected devices

Controller decides on the sub-set with different policies like rule based, priority based, time based, etc. In ambient applications, controller takes presence detection and user localization inputs to make a decision.

This paper proposes ambience based visual notification in connected devices and accessories. Devices are connected in home networks, including intra-home networks. Framework proposed in this paper makes use of visual notification predominantly. Visual notification along with audio and feel based feedback (ringtone and vibration) gives unique ambient experience to end user, which is not the scope of this paper.

Visual notification is useful for deaf people. It is also useful if a person is not present in same place as audio feedback (For e.g., another room). Some cases audio feedback is not present / enabled for a device (For e.g., a mobile phone in silent / meeting mode).

The rest of the paper is organized as follows: Section 2 details the existing state of art using in the framework. Section 3 briefs proposed solution. Section 4 gives describes various components used in different scenarios. Practical realization in

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the framework when connected to controller is also discussed. Section 5 gives use cases based on the framework. Section 6 gives simulation results of the framework.

II. Related Work

Following is related work from market and research fields relevant to the concept in the paper.

A. Device Casing

Sony released Xperia U with color changing illuminating notification bar [4, 6]. The transparent band on phone illuminates when using certain applications. For example, when an incoming call arrives, and when an alarm sounds. It then fades out after a few seconds to save power. The color of the illuminated band varies depending on the theme set. When viewing photos in Gallery, the color changes according to the photo selected. When play music with the music player, the color changes every time a new album cover is displayed. Transparent band requires power to show and maintain the color display at that time.

AT&T mobility introduced with mobile casing having a pixel based display [7]. Various display technologies like Ink based, OLED, LCD, etc. are used to change the content on casing. Advantage with this approach is that image, video and theme patterns are displayed on casing. On flip side, these materials are expensive and also not robust to wear and tear.

Other materials like thermo-chromic / photo-chromic materials can be used as surface coatings. These materials change color based on temperature and light changes. This is better than having same color at all times of day, but the material cannot be controlled for color change using software.

B. Device Accessory

Color notification mechanism is not done for accessory, even though they are connected for various service profiles.

C. Device Connectivity

Where multiple CE devices are present in different places (Rooms, cities, etc.), devices are required to connect to controller (For e.g., Home controller). Presence detection and user localization technologies play a major role while working with ambient applications.

Color changing of CE devices takes presence detection and user localization technologies into consideration for user notifications.

D. Presence Detection & User Localization

The problem of using presence detection and user localization in smart homes has been covered to a great extent in research proceedings in last decade [11].

Rahul Swaminathan et al worked on object recognition based on image localization and registration [18]. Novak et al worked on a case which is dependent on activity of a person in smart home [19]. For the presence detection and localization various sensors would aid: visual (camera, 3D camera), audio (Microphone array) and passive infrared (PIR sensors) [12, 13, 14, 15, 16, 17, 20]. Some of these works consider the ambience of the home network also.

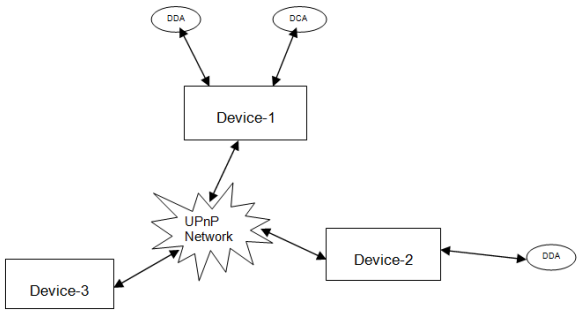

Fig. 2. Connected Devices and Accessories in UPnP Network

E. Nano Materials

Nano coatings reproduce a defined spectrum of colors based on the nano particles. They change to a specific color in about a second on applying voltage. On applying a voltage value, coating changes to a color. Changed color is retained even after voltage is turned off. Nano materials are inexpensive when compared to other materials discussed previously. Nano scale crystalline particles are controlled using a low grade magnetic field, which is used to affect the spacing of the colloidal nano crystals and thereby controlling their ability to reflect light and change color. Nano energia is one of the companies working on nano paints [1].

Changeable color nano paints is gaining popularity in last decade. Many industries are in research stage of using this material. Ex. Auto industry, consumer electronics, etc. [8, 9]

So as to address the problem, we propose an idea to change the color of connected accessories in Home Network based on events triggered in CE devices. Home controller takes decision to determine a target device set based on inputs from presence detection and user localization. Fig.1 shows UPnP based home network [2, 10].

III. Proposed Solution

DynaSurface is an end-to-end framework for device notifications using Nano paints in connected devices. Devices and their accessories are connected using a short range communication technology (e.g., Wifi, Bluetooth, Zigbee, etc.). When the devices are connected in Home network or inter-home network, a home network protocol like UPnP is used for connectivity and service discovery.

Even though some applications on device change notification color in above cases, this feature is not available for downloadable applications as open API.

Devices and their accessories are painted with nano paints. They change color when subjected to controllable programmed voltage through software. Applications on the device make use of the API exposed by the device platform. This API includes

both event trigger and notification handling. Preloaded and downloaded applications make use of the API.

A device / accessory will have region(s) coated with programmable nano paint. A region supports programmable color range. A region in a device supports a command set. A command (e.g. get current color, set color) accomplishes a unique task with a device region.

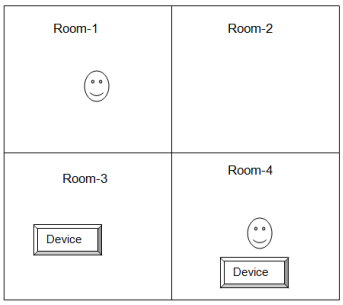

Fig. 3. Devices, Accessories and People at different rooms

In case devices are connected to a controller (e.g., home controller), controller makes a graph topology of devices and accessories at an abstract level. While registering a device / accessory, controller notes the regions, color set of a region, command set of a region. Connected Device List (CDL) is set of devices and accessories (DDA and DCA) registered with controller. CDL is maintained at controller. In the example home network in Fig.2, Device-1, Device-2, Device-3 and their accessories are CDL.

Controller takes care of event registration and notification handling from devices and accessories in the network (e.g. home network, remote-home network). Controller also registers the presence detection and user localization sensors in the network.

An accessory is defined as an entity with passive work scope. An accessory is connected to a device or controller – Based on physical connectivity, accessory is either a Device direct accessory (DDA) and Device connected accessory (DCA). DDA is directly connected to device using physical connectors like USB, Micro-USB, etc. DCA is connected to device using short range communication mechanisms like Bluetooth, Wifi, Zigbee, etc. Fig.2 shows an example home network connecting devices Device-[1-3]. Device-1 is connected to accessories with physical connector and wireless connection. Device-2 is connected to accessory by a physical connector.

Events are registered at a device application. Notification handler registration for an event is also done at device. If the device is connected to controller, then the event and handler are registered with controller.

Device notification discussed in this framework done using color change. Color change is visual notification and device/accessory handling notification; need to be in visual range of a person.

Devices and their accessories in the framework are present at different locations. For example, devices in home environment are present in different rooms. Devices in remote home network are present in different part of the world connected using internet. 2 cases exist where target person is "*any person*" or "*specific person*". Either case, devices in visual range are to be identified to handle color change notifications. Target person is identified based on location, presence detection and user localization inputs to controller. Presence Device List (PDL) is set of devices aid in collecting location, presence detection and user localization at different locations. In case target is "*specific person*", sophisticated user localization mechanisms required. Fig.3 gives an example scenario.

Fig. 4. A refrigerator SAP change color in SCS in response to an event.

Controller determines the target device set, to show notifications, from CDL. Target set is either a subset / full set of CDL. For event, decision on CDL subset / full set notification, is done at registration time.

IV. DynaSurface

A. Framework Overview

3 entities are defined as part of the DynaSurface framework – controller, master and slave. "***Controller entity***" is deployed on controller to perform the controller activities. "***Master entity***" is deployed on devices to do controller interaction and perform actions on accessories. "***Slave entity***" is deployed on accessory to respond to master requests.

Framework is defined mainly in 3 parts. First part talks about the device and accessory using the framework. Second part deals with device and accessory capability handling. Third part deals with the case where devices and accessories are connected to home controller.

B. Device & Accessory Capabilities

Supported accessory portion (SAP) is portion of device / accessory surface coated with programmable nano paint. A device/accessory in this framework contains one or more regions that are independently programmable to change color. Fig.4 shows an example, when a refrigerator changes color of upside region programmable independently for color change.

Supported Color Set (SCS) is color set of a device / accessory region programmable using software. Nano paint coated on a device need not always support a color range of nano point coated on another device. For e.g., a mobile phone case has 10 colors and a refrigerator has 2500 color sets.

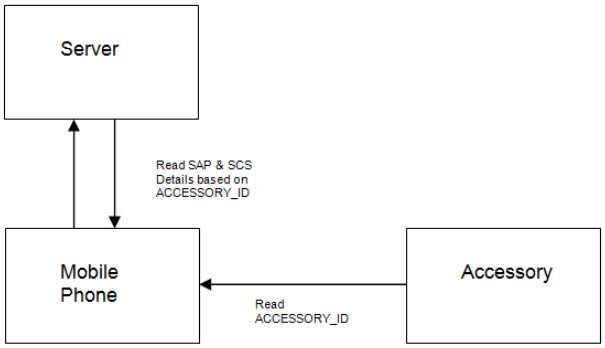

Fig. 5. Server Interaction for Accessory Information

Command Set (CS) is list of commands supported by SAP. SET / GET commands are defined as part of the framework. Fig.6 shows two commands for each supported accessory portion – setcolor and getcolor along with the parameter list.

Capability list (SAP, SCS, and CS) of a device is initialized at boot-up time. Accessory capability list is read by device from accessory, when both are in contact, and stored at device. For e.g., when mobile phone is connected to car cradle, SCS list of car cradle is read by mobile phone from car cradle. This list is communicated as a XML / JSON file.

When device is registered with controller, device and connected accessories capability list is also sent to controller. Further, if an accessory is connected / disconnected, controller is updated with the connected list accordingly.

C. Retrieving the Capability Set

Accessories are embedded devices and some of them have limited memory. An accessory is given an ACCESSORY_ID. Based on ACCESSORY_ID, device / controller reads the capability set from accessory. If accessory does not respond to the request, then device connects to data server and gets the capability list. Fig. 5 shows an example case.

```
<msml version=1.1>
<scs name="buttoncolors type=list>
   red,
   pink,
   blue
</scs>
<scs name="bodycolors type=range start="#FF0000" end="#FF00FF"></scs>
<spaset>
        <spa name ="body" scsset="bodycolors" default= "#FE0000">
        <spa name = "buttons" scsset="buttoncolors" default= "red">
</spaset>
<commands>
        <command name="setcolor" param1="spa name" param2="color code">
        <command name="getcolor" param1="spa name">
</commands>
</msml>
```

Fig. 6. DeviceAccessorySupport.xml

Capability set is communicated between devices, accessory, controller and data server in a structured manner using XML / JSON format. Fig.6 shows an example capability set containing SAP, SCS and CS.

D. Device Side – "Master Entity"

DynaSurface "Master Entity" device side platform takes following responsibilities a) Initialization of self-capability set on device platform. b) Register connected accessories and their capability sets on device platform. c) Register self and dependent accessories and capability sets with controller. d) Provide API set to pre-embed and download applications to register event and notification handlers with device (self) platform and optionally with controller if connected. e) Provide location and presence inputs of self and connected accessories to controller for notification handling.

Event registration is only done at device applications. It is not possible at either accessory or controller. Set of APIs are exposed to applications for registering events and notification handling. API supports 2 types of functionality – 1) event handling 2) color handling. Event handling APIs - register event and trigger event. Color handling APIs – set color, get color list and get current color.

Color handling APIs are mapped to command set for a region at device / accessory. A region need not support one or more commands, depending on the support provided by device / accessory. Notification handlers at device and controller take the command set support in consideration while deciding the Target device set.

E. Accessory Side – "Slave Entity"

An accessory is connected to a device or controller – For e.g., device cover, device add-on cover; BT head set, speaker, docking station, health device, watch, wall paint, etc.

From the context of this framework, 2 types of accessories are defined. 1) Slave accessory and 2) Direct accessory. DynaSurface "Slave Entity" takes following responsibilities 1) Keep a registry of accessory capability set and initialize at boot up time 2) On connecting with a device or controller, provide inputs on capability set and location 3) Respond to supported

command set from device or controller. Both types of accessories have "Slave Entity" responsibility.

On connecting a slave accessory to device, "DynaSurface Master Entity" at device platform is updated with new accessory capability set. If device is registered with a controller, accessory capability set is updated by device with "DynaSurface Controller Entity".

A direct accessory is connected with controller without an intermediate device platform. On connecting a direct accessory to controller, "DynaSurface Controller Entity" at device platform is updated with new accessory capability set. A direct accessory connects to controller using a home networking technology like UPnP, unlike a slave accessory which connects directly.

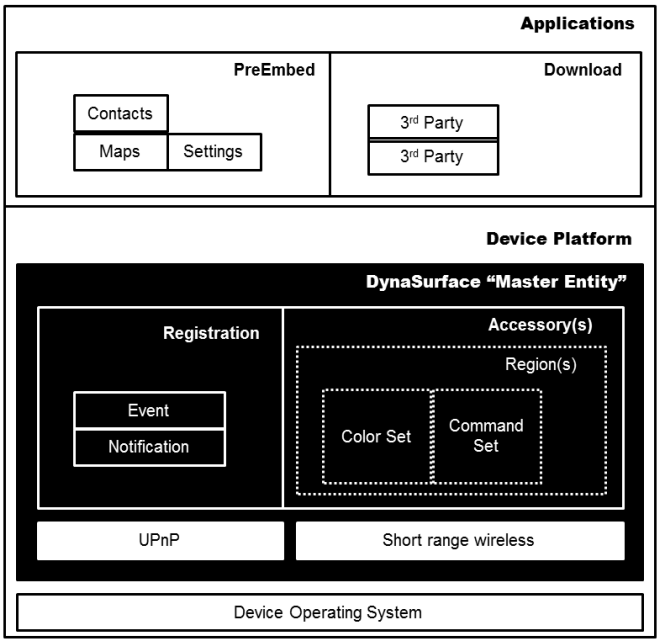

Fig. 7. Device side architecture

F. Controller Side – "Controller Entity"

Controller registers devices and events, handling notifications for both home network and remote-home network cases. Controller also registers the presence detection and user localization sensors in the network.

DynaSurface "Controller Entity" at controller takes following responsibilities a) Register connected devices, slave accessories and direct accessories; and their capability sets. b) Maintain CDL (Connected Device List) and location information c) Maintain PDL (Presence Device List) for presence detection and user localization. d) Register events and notification handlers from devices. e) Respond to event triggers from device events. f) Collect presence detection and user localization inputs from PDL g) Decide on the target device set based on inputs from PDL and CDL h) Trigger commands to target device set to show notifications.

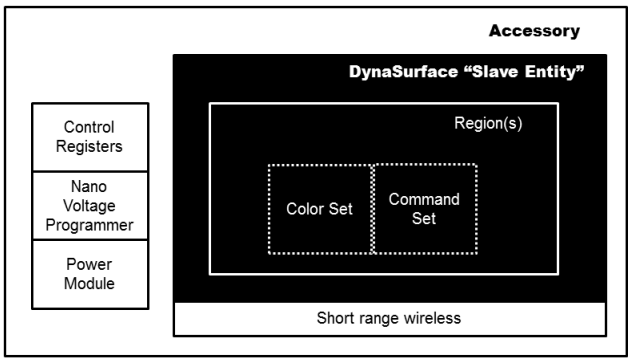

Fig. 8. Accessory Architecture

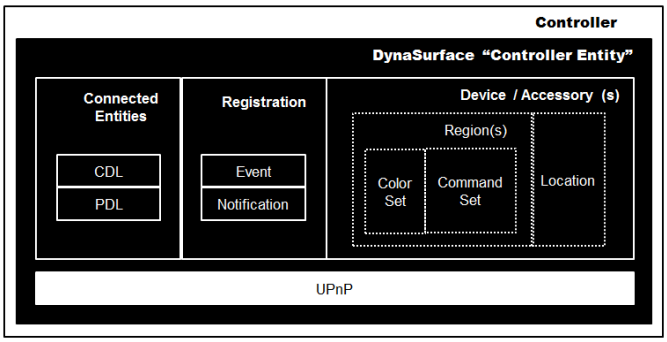

Fig. 9. Controller Architecture

G. Device-Accessory Command instructions

Device platform "Master Entity" issues commands to "Slave Entity" for color handling. "Slave Entity" receives the commands and interacts with device memory and control registers to execute the command. Fig.10 shows entities at both device side and accessory side of the framework on a "Slave Entity" present on slave accessory. Similarly a "Slave Entity" on direct accessory is connected to "Controller Entity" and responds to commands from controller.

H. Connected Entities in Device Network

Devices, accessories and direct accessories are connected to controller (e.g. Home network controller). Controller maintains CDL, a hierarchical list of connected entities. Fig.11 shows corresponding CDL for home network shown in Fig. 2.

2 Presence lists are maintained at controller, PDL and DPL. PDL is for collecting person presence data (location, presence detection, user localization, etc.) in the network. Sensors in the PDL are grouped at first level for a specific presence input, and then on location basis. DPL (device presence list) is to keep track of device presence information. Devices are grouped based on location. Fig.12 and Fig.14 shows sample PDL and DPL.

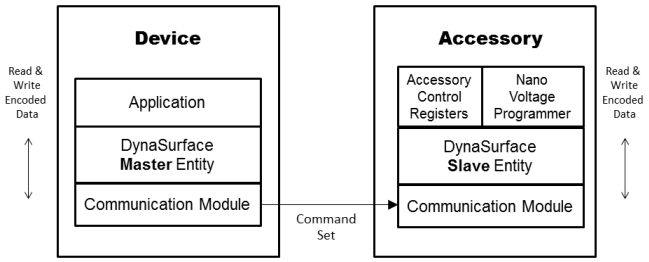

Fig. 10. Device - Accessory Communication

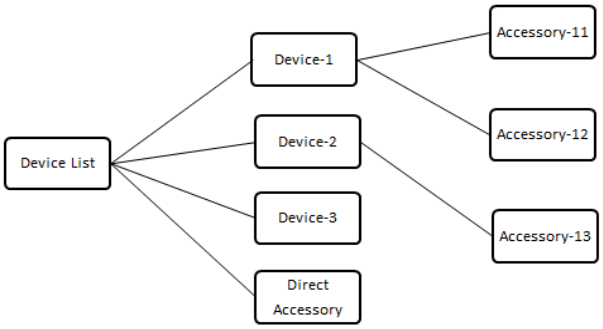

Fig. 11. Sample CDL for network shown in fig.2

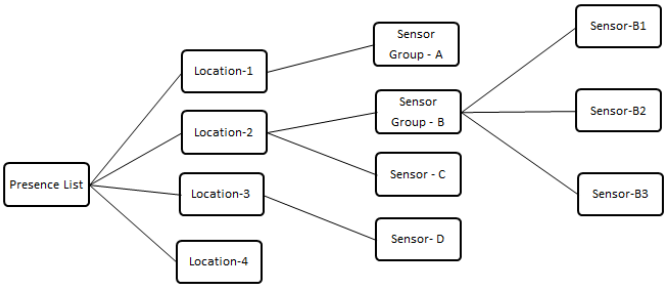

Fig. 12. Sample PDL

I. *Deriving Target Set from CDL*

Even though color change notification mechanism works well when notified to all connected entities, it would be effective when used with location, presence detection and user localization inputs. Various sensors - camera, 3D camera, RFID, voice samples, etc. are used and researched for ambient applications. Controller increase overall effectiveness of color change notification along with the ambient intelligence.

Person presence list (PPL) is derived from PDL. Fig.13 shows that there are people present at LOCATION-1, LOCATION-2 and LOCATION-4. Presence info is also derived from DPL for all connected entities. Fig.14 shows a DPL arranged on location basis. Target set is derived from DPL based on positive location from PPL. Based on Fig.13 and Fig.14, target set marked in BLUE color.

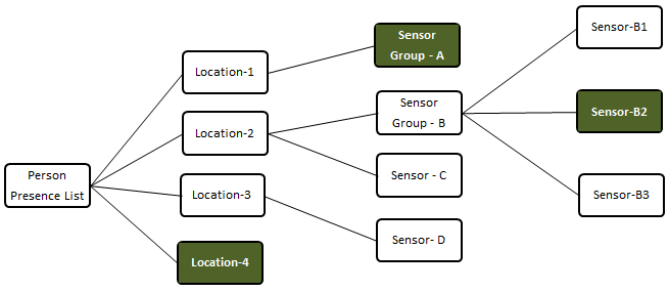

Fig. 13. Person Presence List

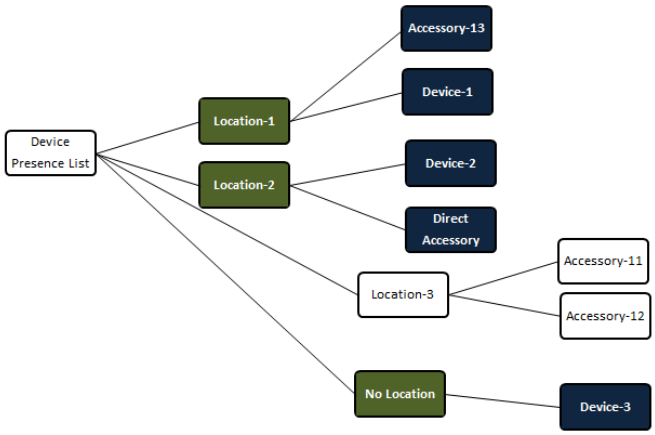

Fig. 14. Device Presence List

J. *Realization in Home Network*

Universal Plug and Play (UPnP) is a set of networking protocols that permits networked devices, to seamlessly discover each other's presence on the network and establish functional network services for data sharing, communications, and entertainment. The UPnP architecture supports zero configuration networking. An UPnP compatible device from any vendor can dynamically join a network, obtain an IP address, announce its name, convey its capabilities upon request, and learn about the presence and capabilities of other devices. UPnP technology can run on many media that support IP including Ethernet, IR (IrDA), and RF (Bluetooth, Wi-Fi). No special device driver support is necessary. [3]

UPnP is base protocol for home network and intra-home network connected devices in the proposed framework. As this service is not part of the standard services list offered on UPnP, this service can be added as extended service on top of basic services and capabilities provided by UPnP as show in Fig. 15. Fig.16 gives end-to-end example scenario of event handling in home network.

K. *Event notification handling in Home Network*

Key point proposed in the paper for DynaSurface framework is, devices change color responding to an event. There are multiple entities connected in the network and each entity contains multiple regions, to handle color change notifications.

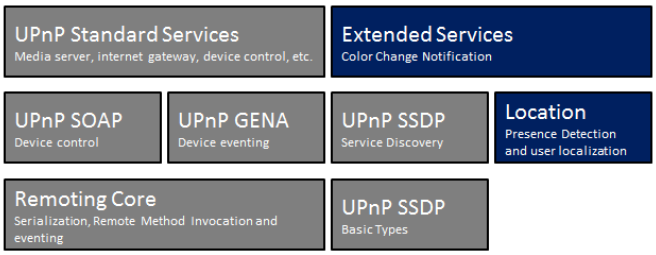

Fig. 15. Home controller software architecture

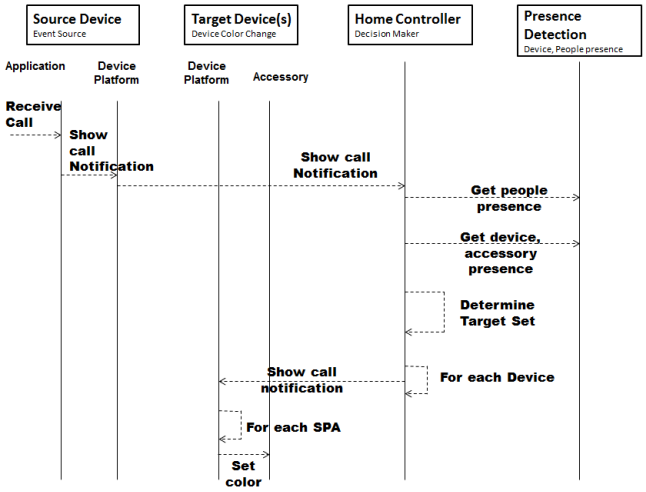

Fig. 16. Event flow between device(s) and home controller for call notification

A good user experience needs a color change notification with nearby shades for target device set. 2 options exist in the case – at event registration and event notification. At event registration time, "common color" set is provided for user selection. In case device is connected to controller, device gets the "common color" set from controller for user selection.

Second option is at event notification case. In this case, device / controller decide on a "request color". Each connected entity receives the request and maps the "request color" to a "supported color".

Fig 17(a) shows a scenario where a device (Device-1, in this case) issues command to each connected entity to set a different color. Fig 17(b) shows a scenario where a controller issues notification with a "request color" (GREY in the example). Connected entity maps the "request color" to "supported color" with near shades. In this example, connected entities mapped GREY to LIGHT GREY, DARK GREY and DARK BLUE from their supported color set.

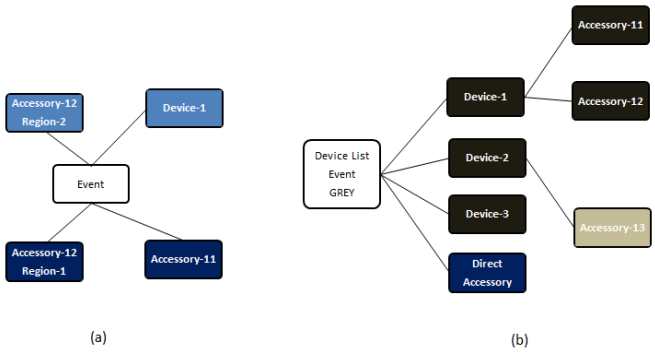

Fig. 17. Notification handling at connected entities in response to an event. (a) Device responding to an event (b) Controller triggers notification handling for an event to connected entities with "GREY COLOR". Devices respond to "requested color" changing to "supported color".

V. USE CASES WITH DYNASURFACE

Following are some applications & relevant use cases for programmable devices and accessories. While selecting the use cases for evaluation, we decided to go for simple use cases which would be used by most of the people, than covering complex use cases. Main intention being that the framework discussed here is targeted for consumer products used by people from all walks of life.

A. Contacts Application on Smart TV

Smart TV user selects a color for a particular contact / contact group. When a call comes from the particular contact / contact group, color notification is given to Target Set from network.

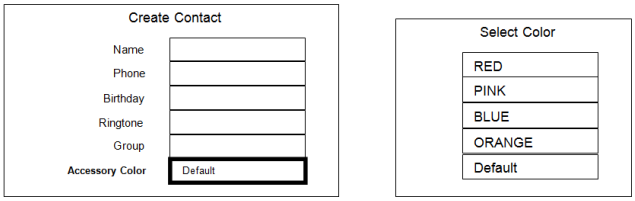

Fig. 18. Contact application view (a) Notification color selection (b) List of colors to select

B. Mobile Profile Settings

In profile settings, device user selects a color to a profile for notifications. Fig.19 gives sample screens for the scenario.

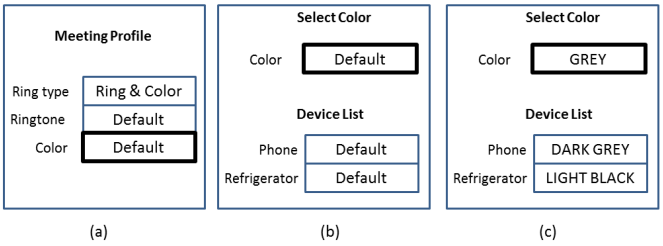

Fig. 19. Device profile settings (a) Edit Profile (b) Select color – List of devices retrieved from controller (c) Once a color is selected, mapped color for each device in network is displayed.

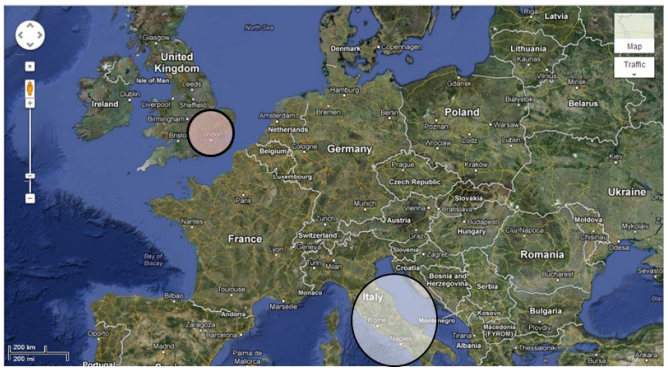

Fig. 20. Geo based tagging for changing mobile phone color (a) London in UK is tagged for Pink color (b) A large portion of Italy is tagged for White color

C. Geo based Notifications

This use case explains notification mechanism integrated to maps application on a mobile / tablet device. A region on map is geo-tagged to a color as shown in Fig. 20 for changing device casing color. If the user is in the region after tagging, color of device is change to selected color of the region.

D. Novel Applications

Notification mechanism is integrated to any 3rd party application for changing color. A use case can be developed to changing color of a connected wall coated with nano paints. Same is extendable to multiple devices in home network. As shown in Fig.21.

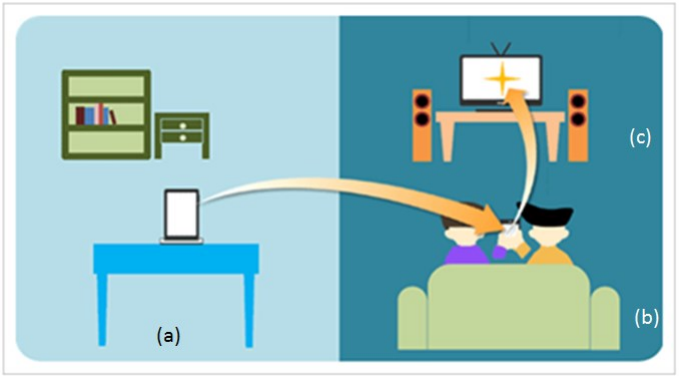

Fig. 21. An example home network (a) Phone in study room (left side) receives call (b) Home Network platform identifies people in living (right side) room (c) Color change notification displayed on TV present in living room

VI. Simulation

Even though nano paints are being researched and evaluated for commercial purpose, devices coated with actual paints are not available at this point of time for evaluation. Because of this reason, we found simulation as a better way to work on and showcase the concept.

UbiREAL is a simulator for developing and testing applications for a smart space or a smart home. UbiREAL provides functions for placing virtual devices such as sensors and information appliances in a 3D virtual space. With this simulator, software developed using UPnP (Universal Plug and Play) protocols can be executed in the virtual space without modification, and virtual devices in the simulator and real devices can communicate and be used at a time. [21].

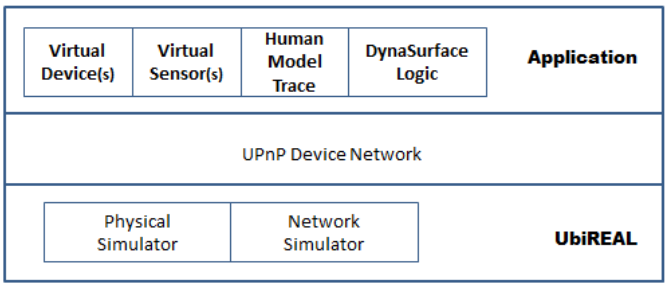

Fig. 22. DynaSurface as an application using UbiREAL simulation

To demonstrate the utility of the framework as well as presence detection and user localization components described earlier, we implemented an application using UbiREAL simulation.

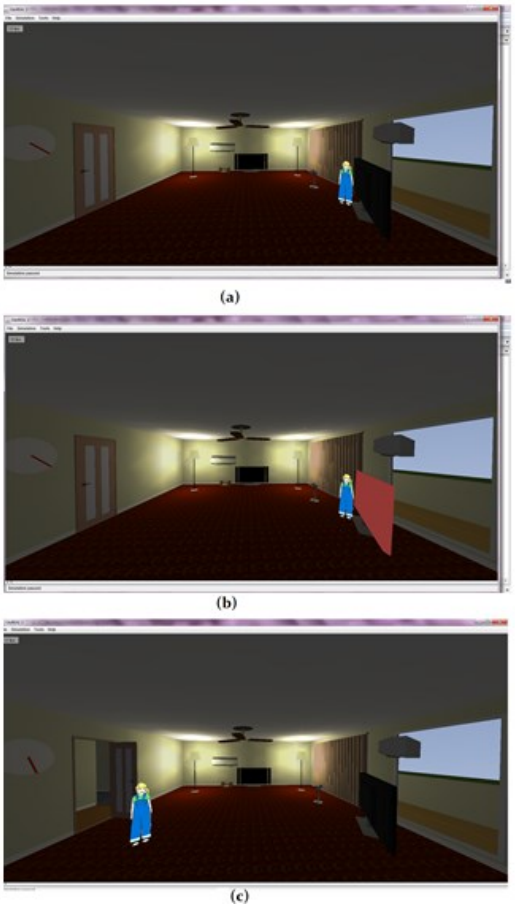

Fig. 23. UbiREAL based simulation. Room contains a human model, 1 small TV, 1 big TV, 2 ACs (a), (b) Human model is near big TV. On reciving an event, only big TV changes color. (c) Human model is far from all the 4 devices. On receiving the event, none of devices change color.

Application requires following components (a) CDL - Virtual devices in home network (b) PPL -Virtual sensors to detect human presence (c) Trace to define the path of human model in a room (d) Logic to determine Target set. In our experiment we successfully achieved the system to emulate the devices, sensors and target set selection in home network.

VII. EVALUATION

As the framework proposed is for consumer products, used by people from all walks of life, it is essential to evaluate for usability. Feedback is collected from 26 volunteers using questionnaire shown in Fig.24 for the evaluation. Exploratory type of usability test is used to evaluate the intuitiveness of the proposed concept.

Name Gender

Age Date

Feedback Arena	Evaluation Parameters	Parameter Range	Comment
DynaSurface Notifications	Usefulness in daily life	Strongly disagree 1 … 2 … 3 … 4 … 5 … 6 Strongly agree	
	Power Consumption efficiency	Not Important 1 … 2 … 3 … 4 … 5 … 6 Important	
	Notification Usage Standalone	Low 1 … 2 … 3 … 4 … 5 … 6 High	
	Notification Usage in Home Network	Low 1 … 2 … 3 … 4 … 5 … 6 High	
	Notification to ALL / Target Device(s)	Target 1 … 2 … 3 … 4 … 5 … 6 All	
Use Cases	Contacts Application	Less Useful 1 … 2 … 3 … 4 … 5 … 6 Very Useful	
	Profile Settings		
	Geo Notifications		

Fig. 24. Usability evaluation Questionnaire

All the volunteers are professionals in the age group of 23 and 34 and each of them own at least one smart device (smart phone). Around 60% of them either own or knows how to use a smart TV. 18 are male and the rest are female participants. As the proposed framework is an ambient application and optionally used in a home network, it is important to recruit lead users who knows how to use smart devices in home environment.

Following are the finding of the usability study. Majority users felt that ambient notifications discussed are useful to them (avg score 4.1) and power consumption is important (avg score 4.6). Users felt that ambient notifications are useful better in a home network than standalone (avg score home network – 5, standalone – 3.8). In case of home network usage, 50% of users want target device notification and the rest want all device notification.

Use cases are the lifeline for the acceptance of ambient notification. Contacts use case fared better than profile settings and geo notification use cases as part of the evaluation (avg score contacts 5.1, profile settings 4.8 and geo notifications 4.8).

VIII. FUTURE WORK

There are multiple directions in which our work can be extended in the future. At the moment we have only implemented simulator model for the framework. This can be implemented on actual android mobile phones and tablets integrated with commercial home network solutions like Samsung Link [10]. Also we can port the framework to embedded samples coated to nano paints. Otherwise, framework simulation on network emulators like NS3 is also an option. Either way, performance measurement for real-time color change is planned in home network. The framework needs to notify changes timely according to a performance degree that might be defined according to the final applications and target users.

IX. CONCLUSION

We have proposed a method to give visual notification to users in a network based on presence detection and user localization sensor inputs. This has been simulated using UbiREAL, an open source smart space simulator where communications and state changes of virtual devices are visualized in virtual space. This framework would enable an enhanced user experience for visual notifications, optionally along with audio feedback. Along with the framework, material is needed for visual notification. Nano paints are selected for color change material because of cost and performance considerations (real time color change and power consumption). In fact, for devices based on battery power (Laptop, tablet, mobile phone, etc.) practically no options available with power consumption capabilities comparable to nano paints. As a result, nano paints are obvious choice for the proposed framework. Framework study is concluded by doing usability study for evaluation.

AUTHOR CONTRIBUTIONS

Samudrala Nagaraju developed the original concept, material selection, DynaSurface framework design and simulator tool selection. B.M. Manjushree developed the framework simulation using UbiREAL tool. Authors want to thank the UbiREAL team, for making the tool open source for network simulation and visualization for academic and research purpose.

REFERENCES

[1] Auto Nano Paint Coatings : www.nanoenergia.com

[2] UPnP Forum Industry initiative : www.upnp.org

[3] UPnP Wiki : https://en.wikipedia.org/wiki/Universal_Plug_and_Play

[4] Sony Xperia S-LED transparent strip : http://www.xperiablog.net/2012/04/01/xperia-s-led-mod-changes-colour-of-transparent-strip/

[5] Sony Xperia detachable bottom cover : http://www.sonymobile.com/us/support/faq/xperia-u/personal/can-i-change-the-colour-of-the-bottom-cover-1/

[6] Sony Xperia transparent band color change : http://www.sonymobile.com/in/support/faq/xperia-u/personal/how-do-i-change-the-colour-of-the-transparent-band-1/

[7] US Patent 20090215498 A1 - Devices and Methods for Changing the Appearance of a Mobile Communications Device

[8] Advanced Materials - Use of advanced materials in enhancement of modern technology - http://iste.nitb.in/attachments/smartMaterial.pdf

[9] Nanotechnology in High Performance Paint Coatings - http://www.ajes.in/PDFs/08-2/2.%20Nanotechnology-A%20boon.pdf

[10] Samsung All Share / Samsung Link : http://www.samsung.com/global/allshare/pcsw

[11] B.Mrazovac, Bjelica, M.Z.; Papp, I.; Teslic, N. Smart Audio/Video Playback Control Based on Presence Detection and User Localization in Home Environment. In proc ECBS-EERC '11 pages 44 – 53

[12] Mrazovac, B.; Bjelica, M.Z.; Kukolj, D.; Vukosavljev, S.; Todorovic, B.M. "System Design for Passive Human Detection Using Principal Components of the Signal Strength Space", Engineering of Computer Based Systems (ECBS), 2012 IEEE 19th International Conference and Workshops on, On page(s): 164 – 172

[13] Stein, D.; Lehmann, M.; Ploennigs, J.; Kabitzsch, K. "Sensors, models and platform for ambient control", IECON 2012 - 38th Annual Conference on IEEE Industrial Electronics Society, On page(s): 4853 – 4859

[14] Canesta 3D sensor, http://en.wikipedia.org/wiki/Canesta

[15] K. Kwak, and S. Kim, "Sound source localization with the aid of excitation source information in home robot environments," IEEE Trans. Consumer Electronics, vol. 54, no. 2, pp. 852-856, May 2008

[16] N. Yoshiike, K. Hashimoto, K. Morinaka, M. Kawaguti, S. Tanaka, "360 type human information sensor", Sensor and Actuators A77, 1999, pp. 199-208

[17] V. Nuhijevic, S. Vukosavljev, B. Radin, N. Teslic, M. Vucelja, "An Intelligent Home Networking System", International Conference on Consumer Electronics, Berlin, Germany 2011

[18] Swaminathan, R., Nischt, M.; Kühnel, C. Localization based object recognition for smart home environments. 2008 IEEE International Conference on Multimedia and Expo. Page(s): 921- 924

[19] Novak.M., Binas, M.; Jakab, F. Unobtrusive anomaly detection in presence of elderly in a smart-home environment. Page(s): 341 - 344. ELEKTRO '12

[20] Sungjae Hwang, Kwangyun Wohn. VibroTactor: low-cost placement-aware technique using vibration echoes on mobile devices. Page(s): 73 - 74. IUI '13

[21] UbiREAL – A Smartspace Simulator. http://ubireal.org/