# Application as a Sensor (AaaS) Approach for User Attention Sensing

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## Abstract

This paper proposes a novel "Application as a Sensor" (AaaS) approach for user attention status sensing in mobile and ubiquitous computing where user attend to ubicomp-related goal-directed tasks that usually involve in "applications". By using application-specific knowledge on user's attention status while manipulating applications running on multiple mobile devices, the underlying system can sense user's current attention target and "breakpoint"[16] that can be used for further attention-aware adaptation for maintaining user's productivity, in real-time, in mobile devices, without dedicated external psycho-physiological sensors.

## Biographical Sketch

Tadashi Okoshi is pursuing his PhD in ubiquitous computing from April 2013, under Professor Hideyuki Tokuda's supervising in Graduate School of Media and Governance, Keio University. The expected date of completion is March 2016. Before that, he had several year experiences as a product manager at social media start-up businesses. Previously, he pursued his research in the areas of smart space, ubiquitous computing, and mobile computing. He obtained M.S. in Computer Science from Carnegie Mellon University in 2006. He obtained M.A. in Media and Governance (2000) and B.A. in Environmental Information (1998) from Keio University.

## Introduction

"Interruption" for users by notifications in multi-tasking environment has been a greater problem since amount of user's "attention" remains unchanged while amount of information provided has been increasing in emerging ubiquitous computing age.

The number of networked computing devices of users themselves, as well as those embedded in surrounding environment and space have been drastically increasing. Users tend to own, manipulate, bring, and utilize (even simultaneously[2]) increasing number of networked devices[1]. Also the number of applications, services, and communication channels per each user is increasing, being driven by several aspects of technological progress as well as the market trends.

Given such backgrounds, limited resource of **human attention** is the new bottle neck[8] in computing. From the view point of the human users, these excessive amount of provided information is often called "information overload" in a broad sense. In this research, we will particularly focus on **interruption overload**, distraction for users caused by interruptions based on excessive amount and inappropriate delivery of notifications from computing systems.

## Interruption Overload

Main cause of interruption overload for users is "notifications" from computing systems. The notification to user is originally and essentially designed to provide the information to user more speedy and timely, from outside user's current attention focus.

In spite of the benefit above, typical notification systems which deliver notification immediately, make negative affect on user's work productivity[3, 4, 7, 15] according to previous controlled studies. Also other research found that the gap between user's primary task and interrupting task is another cause of these affect[9]. Since some part of finite resource[17] of human's attention will be allocated to cognition of notifications, "divided attention (DA)" situation causes big performance degradation in memory performance[6] and it leads the negative affect above.

Adaptive notification support, that dynamically adapts notification timing, media, content and so forth according to both current attention status of user and information to be notified, is clearly needed to ease user's interruption overload. This research focuses on sensing of current availability (or load) and the target of user's attention for inference on "when the notification can be fired" and "what information can be notified".

As distinctive characteristics of notification in the recent ubiquitous computing trend described in Introduction, followings are among our research focus.

- **Increasing diversity in types and sources of notifications:** e.g., updates from friends over social network, query of participatory sensing[5],
- **Multiple mobile devices of users as destinations:** e.g., smart phone, tablet, or wearable device.
- **Wider range of urgency level:** e.g., Early Earth Warning (EEW)[11] to which users need to physically react in a few seconds.
- **All-day-long interruption situation:** User's recent life style always with mobile devices makes interruption overload all day long.

Also, this research scopes interruption during users' "goal-directed interactive tasks" which involve in manipulation (reading and/or writing) of content in information space, such as document editing, watching

VOD videos, reading e-books, or playing the games on smart phones.

## Attention Sensing with Application-Specific Knowledge

Towards the inference on "when the notification can be fired" and "what information can be notified", this section introduces our proposing attention status ("timing available for interruption" and "target of attention") sensing which features utilization of application-specific knowledge from application(s) running and being used by users on their multiple mobile devices.

### Principles for Attention Status Sensing

Based on our research backgrounds and scoping, we itemize followings as principles in attention status sensing.

- **Feasibility in mobile devices:** Users carry and use mobile devices, such as smart phones or tablets, as immediate devices for their task applications. Thus the system needs to fit the mobile platform, in terms of energy-efficiency, for example.
- **Real-time sensing:** For the adaptation on the fly, the sensing needs to be done in real-time.
- **Applicability for diverse types of notification source:** System needs to be applicable and easy to be deployed for diverse types of notification source.
- **Affinity with all-day-long use:** The sensing needs to be done all day long as long as the user's surrounding notification system is available.

### "breakpoint" as a Temporal Target for Interruption

As a temporal target point in sensing appropriate timing for interruption, we plan to utilize concept of "breakpoint"[16] originally found in psychology field. Boundary between two adjacent actions that human's perceptual system can segment inside an activity is called "breakpoint". There are at least three granularities of breakpoints, Fine, Medium, and Coarse, that can be reliably detected by users in case of interactive computing tasks[14].

Related work in sensing user's attention availability or cognitive load in real-time needs at least two psycho-physiological sensors[10] even in non-mobile situation. Instead, our approach is trying to sense more coarse-grained but easy-to-measure indicator from which eventually appropriate timing for notification can be inferred, only through user's existing carrying devices.

Further study and is needed for applicability and feasibility of this model for our research scope and target, although related research have shown that deferral of notifications until users' sensed breakpoints reduces interruption cost in terms of resumption lag and subjective frustration value[3, 12, 13],

### "Application as a Sensor"(AaaS) Approach

Then how does the system sense user's breakpoint timing and target of attention? Our approach is called "Application as a Sensor"(AaaS). It utilizes both compile-time and run-time information from applications running and being used actively on user's multiple mobile devices. "Goal-directed task" focused in this research almost always involve in a corresponding "application" in computing system. Thus, utilizing as much knowledge as possible from the application layer is actually natural.

Representative knowledge to be used is listed as follows.

- **"Expected breakpoint flag":** In development phase, application developer can explicitly embeds information on "expected breakpoint flag" inside the application source code. For example, transition

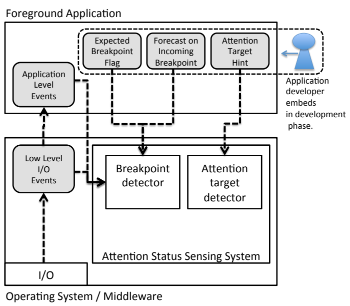


**Figure 1:** System Design of Attention Status Sensing in Single Device

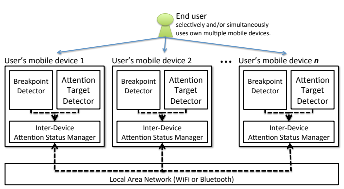


**Figure 2:** System Design of Attention Status Sensing across Multiple Devices

between 2 different screens is a representative candidate of such breakpoint.

- **"Forecast on incoming breakpoint":** In development phase, application developer can explicitly embeds information on forecast on breakpoint in near future. For example, a game application can forecast that "breakpoint is coming in 5 minutes" when a "5 minute stage" starts.
- **"Target of attention":** Based on the run-time content inside the application, such as content of opened files or focused content, the application can export hints on current target of user's attention.

### Systems Design

Figure 1 shows systems overview on attention sensing system in a device, and figure 2 shows systems across multiple mobile devices. In run-time phase, the app knowledge, in addition to the low level I/O (e.g., mouse movements and keyboard types) and application level events (e.g., window activation, menu selection) are passed to Breakpoint Detector. Combining machine learning technique and more explicit and direct hints from the application, breakpoints will be detected in a device. Across user's multiple mobile devices, information on breakpoint will be share in real time and final inference on breakpoint detection will be done across those devices.

## Expected Contribution to the Field

The contribution of this work will be the novel approach, systems design, implementation and evaluation of user's attention status sensing necessary for adaptive notification management. Especially, our AaaS approach that utilizes as much knowledge as possible for inference on user's attention status will reveal new possibility of applications role in computing systems.

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