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Architectural Design of Crowdsourcing Systems with Various Crowds

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Abstract

During the last decade, computer science and applications have seen the rapid development of the crowdsourcing paradigm – a promising new phenomenon for services and Internet-based business model. A key role in crowdsourcing is played by a large number of people – human crowd, engaged by an open call to perform a certain task or to solve a certain problem using their own mobile, touchscreen or other devices for work and communicate via the World-Wide Web. The standard system architecture for leveraging crowdsourcing uses the participation of one or two crowds. This study develops the concept of crowdsourcing in the case of many-to-many crowds. Two cases are considered: (a) a group of crowds to solve different types of tasks per crowd and a group of crowds of end users, and (b) a group of possibly overlapping crowds of workers and a group of crowds of requesters for different types of tasks. Sample projects are showcased.

Keywords: *Crowdsourcing, Architecture Design, Live Video Streaming, Mobile Crowdsourcing, On-Demand System, Spatial Crowdsourcing.*

1. Introduction

The widespread availability of mobile devices and personal computers, along with the development of new ICTs has provided new opportunities for more effective problem-solving or performing various types of tasks using the work and efforts of large groups or crowds of interested persons. In this field, the crowdsourcing (CS) paradigm is increasingly popular having various methods and business models – both in the scientific and practical context. The standard architecture of a CS system considers the performance of a task or the solving of a problem by an undetermined crowd of people, where the task could be divided in small parts. Often, there is a need and/or opportunity to solve several such tasks but by other crowds, which naturally leads to the formation of a network of crowds for solving independent problems. On the other hand, the software implementation of a unifying crowdsourcing project enables this type of network to be executed with more limited technical, programming and human resources. The solution of such problems from the point-of-view of the CS system architecture is the motivation for our study.

According to the latest reports by Deloitte and Cisco Systems, the number of mobile devices and PCs in the world number more than 8 billion and is expected to grow rapidly. Table 1 shows data for the global Internet traffic from 1992 to 2021. From this, the total mobile traffic is expected to increase 2-fold in 2021 compared to 2016. It is also reported the live Internet video to account for 13 percent of Internet video traffic by 2021 and to grow 15-fold from 2016 to 2021 [1].

Table 1: Data for global Internet traffic in gigabytes [1]

Year	*Global Internet Traffic*
1992	100 GB per day
1997	100 GB per hour
2002	100 GB per second
2007	2.0 GB per second
2016	26.6 GB per second
2021	105.8 GB per second

Predominantly, people using personal electronic devices for communication and online work are in their working age, employed or job seekers on the labor market. Their skills in using this type of devices and related software are constantly improving. Along with this, it is observed an increasing amount of the Internet of Things (IoT) on various mobile devices (smartphones, iPhones, tablets, etc.) featuring sensor accessories for creating, receiving and transmitting audio and video data, for measurement and transfer of meteorological data, GPS data on location, etc. [2, 3, 4]. It is expected that by 2020 over 24 billion smart gadgets will support the IoT platforms with information from these going primarily through mobile devices. These hardware capabilities combined with communications technologies facilitate the transfer of information via the Internet. All this enables a large number of people to participate in the performance of individual tasks or parts of tasks outside their regular employment based on the on-demand services principle. This enormous human potential and the growing capabilities of cloud technology for storage and processing of large data arrays are a prerequisite for the development and integration of crowdsourcing systems in their various forms and fields of human activities. The growth of the crowds and their seamless integration in current workflows can have a huge impact on the Internet and society, making it a leading paradigm, which may shape the development of the labor market in coming years [5].

Classic examples of CS are the open systems of Wikipedia and YouTube, where a crowd of individuals with various expertise volunteer to create collectively text and video content to the benefit of the crowd of users throughout the world. A well known example of CS is the human computing platform Amazon Mechanical Turk (https://www.mturk.com), which operates a large marketplace for solving thousands of various „human intelligence tasks" (HITs), set by a crowd of requesters – MTurk clients. Typical tasks, which MTurk allocates among its workers are for example – processing a big amount of images, data clean-up and verification, audio editing and transcription, etc. [6]. A 2015 World Bank report estimated Amazon's Mechanical Turk marketplace has about 500,000 registered workers worldwide, although not all of them are active [7]. Another successful on-demand CS project is Clickworkers (https://www.clickworker.com/) with a million workers who collect different data at the request of a customer and deliver it in real time [8].

With the development of IoT and the huge number of personal touchscreen devices, recently CS finds applications in many other fields. As an example, we can specify the earthquake network project for a crowdsourced smartphone - based earthquake early warning system [9]. Another example is the crowdsourcing approach to enhance the mitigation and disaster management of landslides presented in [10].

For the organization and leveraging of crowdsourcing systems, including such for mobile CS, various types of architectures, systems, infrastructure and cloud services are being developed and studied. These are the subject of numerous papers. In this respect, we have to mention the review papers [11, 12] which summarize the existing main types of Internet based CS systems, their components and features, of the methods and services for data protection, etc. The general types of system architectures and morphology to classify mobile CS applications are presented in [13].

Particularly, it needs to be noted that along with crowdsourcing, crowdfunding is also developing rapidly as a new paradigm for public funding with relatively small contributions, which is growing into economics of crowdfunding [14].

With regard to the issues related to the implementation of a CS project, a lot of attention is given to studying the methods and marketing to ensure participation by a sufficient number of people. In the recent publication [15], an incentive mechanism is introduced to include more participants and to achieve improved quality of services in a mobile crowdsourcing system under limited funding by including two crowds of people – participants in the task and agents between them and the system itself.

The goal of this paper is to develop an architecture concept for a CS system in cases where multiple participating crowds perform various problems. Two conceptual models of systems are considered. The first model is about a CS for creating, sending and receiving large volumes of information in real time. As an example, the expansion of the author's system Footlikers, a mobile crowdsourcing project for live video streaming of amateur football games is considered. By adding sports other than football, such as volleyball, tennis, motor sports, and other races, many crowds are engaged to participate in two different groups (crowds of broadcasters and crowds of fans). The second model of CS system considered is of the on-demand spatial crowdsourcing type, where the participating crowds, unlike MTurk can be dependent and event partially overlapping. Finally, a combination of both models will form a hybrid type crowdsourcing. The examples of system architecture are presented.

2. Theoretical Aspects of Crowdsourcing

The idea of harnessing the skills and knowledge of large groups of people to solve different problems is not new. There are many examples in the past when "the wisdom of the crowd" has been used. For example, in the Netherlands, in 1672, a prize of 100,000 Guldens was announced for the one who managed to raise a black tulip. The lucky one is doctor Berle, who creates the famous dark purple, almost black tulip that is loved by hundreds of people. In 1884, the Oxford Dictionary of the English Language used 800 readers to catalog words. More historical examples can be found in [16].

More recently, H. Rheingold, in his remarkable book "Smart Mobs: The Next Social Revolution" explores the possibilities of mobile devices and introduces the notion of collective wisdom [17].

In the field of computer science, there is still no clearly determined definition of the term crowdsourcing. The concept itself evolves very rapidly over time expanding constantly its field of application and types of crowdsourcing, accumulating an ever increasing number of completed projects. The term was introduced by the American journalist Jeff Howe in 2006, who called crowdsourcing a "business practice that means literally to outsource an activity to the crowd" [18]. Unlike outsourcing, where work is performed by a specific worker or company, with CS the work is outsourced to a large anonymous crowd of workers in the form of an open call [5].

In another definition CS is "a common term referring to a set of distributed production models that make an open call for contributions from a large, undefined network of people" [19]. We will also add the following integrated definition of the term CS as a summary of over 40 interpretations from literature, which is as follows: "Crowdsourcing is a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task." [20].

To varying degrees, CS includes the following main components [8]:

- a clearly defined crowd of committed individuals,
- task and objective
- clear compensation for the crowd for the work and effort put in;
- a defined online participation process (with work, money, knowledge or experience);
- an open call for participation;
- use of ICT.

Currently, the definition is expanded to include additional new components. The next generation CS is classified in four forms: Situated CS, Spatial CS, Crowdsensing, and Wearables CS, as „new configurations of hardware, software, and people as IT-mediated crowds" [21]:

- Situated Crowdsourcing classifies tasks, which can be solved by display hardware (tablets and other touchscreens), and utilizes the skills and intelligence of participants in the crowd to solve human and scientific problems or idea generation [22, 23]. The participation is not directly dependent on the specific physical location of the individual and often the location where work is performed.
- Spatial Crowdsourcing is a new direction, which appeared in recent years. Includes various specific tasks or processing of information, which require crowdworkers to be located at a specific place and time in order to perform them [24, 25, 26, 27]. In sum, this crowdsourcing technique combines active individual input with the task subject of the environment [4].
- Crowdsensing involves active collection of data from the crowd through the hardware of their various mobile devices, mostly smartphones and autonomously transfers these data via Wi-Fi or mobile networks [4, 28, 29, 30].
- Wearables Crowdsourcing is a case where the crowdworker is a hardware device – wearables that allow for the leverage of built-in sensors in hardware devices attached to the human body and/or through apparel or accessories. The participation of the persons themselves is minimal. They passively collect and transmit data only about the specific device user, for example, monitoring their health status, location, etc. [4].

Spatial crowdsourcing also includes the platforms and systems, which offer new interconnected business models, where the tasks for the crowd can be actual physical work or services outside the Internet. Such tasks are for example: delivery of a shipment, cleaning or renovating a home, babysitting a child for a short time, washing a passenger vehicle, etc., which are assigned to various freelance individuals or on-demand companies. Typical examples are TaskRabbit (www.taskrabbit.com), FieldAgent (https://app.fieldagent.net/), and Youpijob (https://youpijob.fr/). Spatial crowdsourcing is suitable for the labor market of the rapidly-developing so-called "gig" economy for seeking and finding short-term and freelance work as opposed to permanent jobs.

3. Conceptual Architecture Designs of Crowdsourcing Systems

3.1 Classical designs

General CS architecture is typically of the following three types: with one crowd and one task, with two crowds and one task, with two crowds and many tasks.

- CS system with one crowd and one task

With classical crowdsourcing, the crowd of people are usually involved in the performance of one common simple task or a more complex task, which is whenever possible, subdivided into smaller simpler, interconnected parts. The model of a CS system with one crowd and one task is outlined as diagram in Fig. 1. If any corrections or additions to the task are allowed, such interactions are designated by two arrows. Examples of this type of CS are the competitions, voting on a given product, air pollution measurement within a city among others.

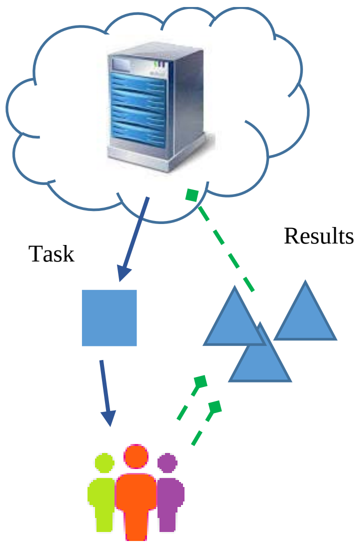

Fig. 1 General architecture of crowdsourcing with one task and one crowd.

• Models of CS with two crowds of participants and different tasks

Many systems include two crowds – workers (or experts) and end users. The diagram in this case for one common task is given in Fig. 2. Examples of such systems are Wikipedia and YouTube. This type of model is suitable for situated crowdsourcing and it does not take into consideration the time and place of performance of the task (tasks). Interactions can take various forms – with or without control and evaluation or without evaluation of any participating party (requesters, system or crowd). Setting a specific task is also not mandatory. For example, YouTube supports a large database of video content, which creation can be considered as a task. For its performance, workers employ themselves by choosing their specific contribution.

Currently, the most widely-user model is that of two crowds and multiple tasks. One crowd (requesters or CS clients) sets various, usually independent, problems to be solved by a general crowd of workers. An example of such an organization is MTurk, as well as all spatial on-demand CS systems. Usually, a direct connection and feedback are required but not always. Fig. 3 shows a diagram of the model for spatial crowdsourcing providing on-demand services.

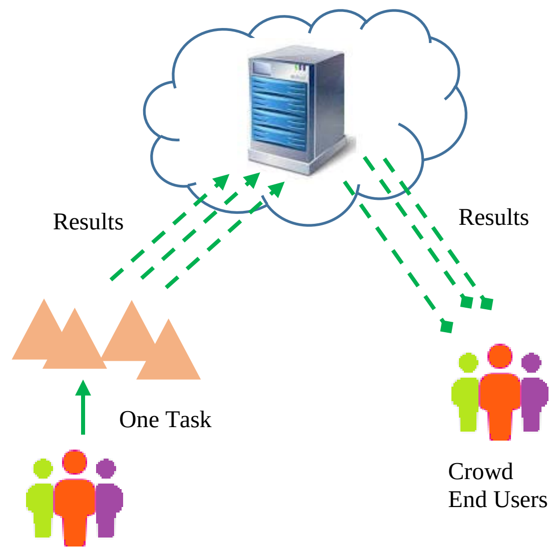

Fig. 2 Crowdsourcing with two crowds and one common task.

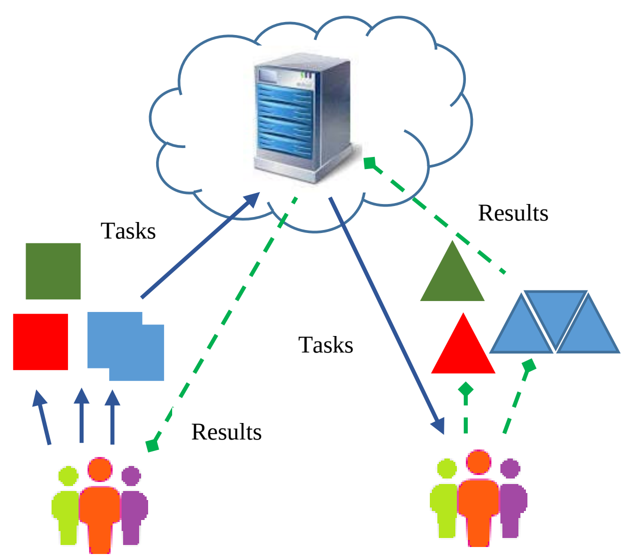

Fig. 3 Crowdsourcing with two crowds and many different tasks.

3.2 Example: Footlikers for mobile live video streaming of football matches

As an example with two independent crowds, we present the author's system Footlikers for mobile crowdsourcing of video content and live streaming of amateur football matches, played in France, Belgium and Luxembourg [31, 32]. The system includes two crowds – broadcasters shooting with their mobile device camera a given football event and another crowd of viewers – fans, who watch the games live on their mobile devices. The broadcasters are volunteers authorized by the system. All users are registered on the Footlikers website. Communication between the crowds is handled by the system's specialized mobile application, running under Android and iOS. Due to the high mobile traffic volume and in order to provide high-quality video streaming, the system uses the services of Amazon EC2 and Wowza engine. The system is enhanced by an additional sink server facilitating the synchronization of relative game time according to the various technical characteristics of the stream and users' mobile devices. The system can be classified as unambiguous spatial CS, since the type of activity is the same but the crowd of broadcasters depends significantly on time and location. A diagram of the system's architecture is given in Fig. 4.

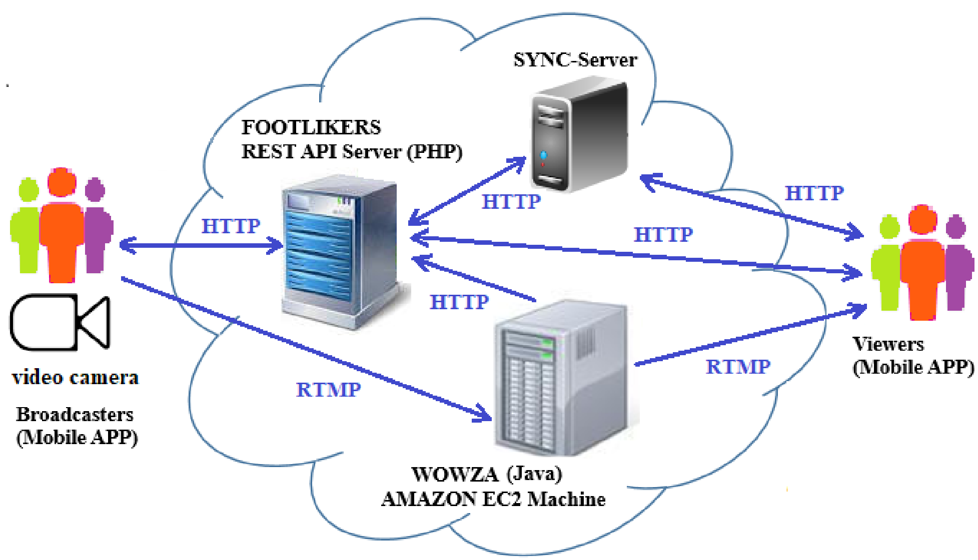

Fig. 4 Architecture design of mobile CS system Footlikers for live video streaming with two crowds.

3.3 Conceptual design of a CS with multiple crowds and tasks

Although some cases of CS with two crowds of participants and multiple tasks can be considered as many-to-many, practically their implementation remains based on the one-to-one principle with two crowds [33, 34]. There are cases where an increase in the number of crowds and solved problems is achieved naturally. As an example, we present a model of Footlikers, when sports other than football are added, such as tennis, volleyball or basketball, which in principle have non-intersecting crowds of broadcasters and viewers. What is more, sports are very different in terms of duration and game rules. The presence of large homogeneous groups of fans leads to the formation of independent crowds, which also applies to broadcasters. Only occasionally some users may participate in two or several crowds. From the point-of-view of CS, it is better that these crowds are serviced individually from the same system, considering the similarity but with different mobile application and the respective processing of Big Data video, considering the total time needed. This leads to a design of the system for many-to-many crowds. The extended model we propose is shown in Fig. 5.

The proposed design has the following advantages: one-off registration of participants and easy access; unified notification of all registered users about new sports events within the entire community; easier implementation of new sports without the need to develop separate CS systems;

easier servicing of video streams; use of a common sink server.

The disadvantages that can be noted are: possibility of system overloading with simultaneous streaming of two or more large sports events; need for additional software solutions to avoid overloading or system failure.

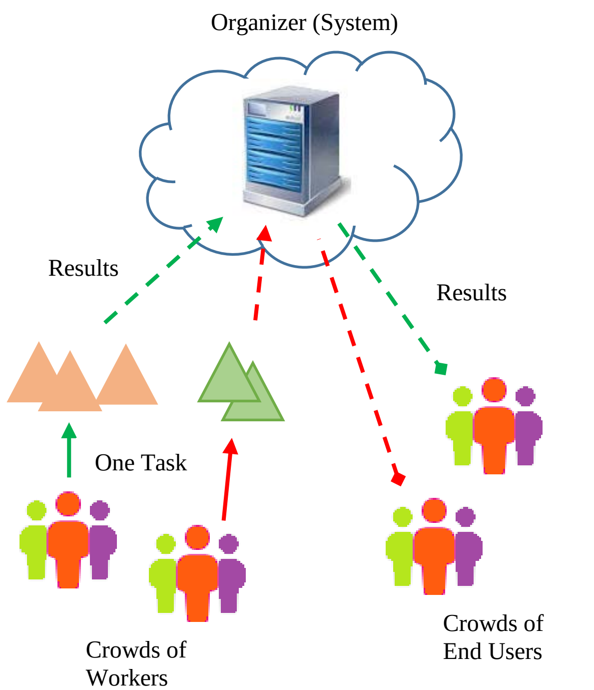

Fig. 5 Architecture design of an extended system with many-to-many crowds.

3.4 Conceptual design of a hybrid on-demand CS: project AssisMe

As a second example, we will review a prototype of a spatial crowdsourcing CS project called AssistMe. This assumes the possibility for different software support when servicing several crowds of requesters and several crowds of workers, called assistants. All participants are registered system users. The objective of the CS system is to expand the standard model of supply and demand for services via the Internet such as TaskRabbit and IT-supported gig economy. Since the demand for services is expanding its scope, in principle, there may be a need for various kinds of services partially or fully – for example, amateur video recording of an event – personal celebrations, fashion collections, cultural events, etc.

Another type of service may arise where a client or requester hold a popular vote or conduct a survey to determine the rating of a new product, etc. In this manner, the CS system shall have to provide different kinds of data processing to its registered users and not only those for finding workers for hourly or one-time work. We arrive at the need to divide the crowds in order to enable different services within the same system of registered users. The proposed design concept for AssistMe is given in Fig. 6. The reviewed case allows for some crowds to be independent and others – partially overlapping in terms of participants.

The creation of a hybrid CS provides the following advantages: unified registration of participants and easy access; guaranteed constant potential crowd; ability to use the social network within the website of the AssistMe system; enhanced personal data protection with payments between assistants and requesters within the system; provision of a growing and diverse range of services by the system.

As disadvantages, we can specify – more difficult software implementation of the system for processing of the different workflows, harder support of various types of services; implementation of a single mobile application for communication; video content control, etc.

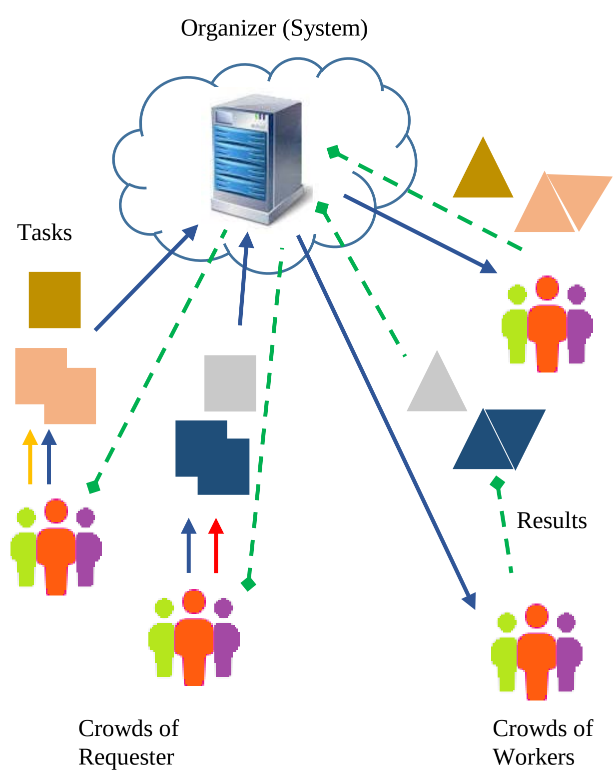

Fig. 6 Architecture design of a hybrid system with many-to-many crowds and differently processed tasks.

5. Conclusions

The paper presents in brief some theoretical aspects and current state of crowdsourcing systems. Particular attention has been given to the architecture design of the CS system in view of participating crowds, types and number of tasks. Cases are showcased where the involvement of more than two crowds in the system has been justified as well as the need for a many-to-many crowd design. Conceptual models are proposed for independent crowds and partially overlapping ones in terms of participants. Two specific project are presented – expanded author's system Footlikers for mobile crowdsourcing of real time video streaming for many sports and a project for a hybrid CS system AssistMe for on-demand services. The advantages and disadvantages of the proposed conceptual models are discussed.

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