FOUNDATIONS OF COMPUTING AND DECISION SCIENCES
Vol. 41 (2016) No. 3
ISSN 0867-6356
e-ISSN 2300-3405
DE GRUYTER OPEN
DOI: 10.1515/fcds-2016-0012

HOW INTERNET OF THINGS INFLUENCES HUMAN BEHAVIOR BUILDING SOCIAL WEB OF SERVICES VIA AGENT-BASED APPROACH

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Abstract: The paper discovers potential human interactions with growing amount of internet of things (IoT) via proposed concept of Social Web of Services (classical social web with smart things - daily life objects connected to the internet). To investigate the impact of IoT on user behaviour patterns we modelled human-thing interactions using agent-based simulation (ABM). We have proved that under certain conditions SmartThings, connected to the IoT, are able to change patterns of Human behaviour. Results of this work predict our way of living in the era of caused by viral effects of IoT application (HCI and M2M connections), and could be used to foster business process management in the IoT era.

Keywords: Internet of Things, Internet of Service, Web of Service, Social Web of Service, business model, Agent-based theory, smart home, virality, digital transformation

1. Introduction

No one in 90s may even thought that in 20 years 4 billion IPv4 addresses will not be enough to satisfy Internet connection demand. Already in 2008-2009 the number of Internet-connected devices exceeded the number of people on the planet that we consider as a starting point of structural changes described in this article. Cisco Internet Business Solutions Group proclaimed it as a start of *Internet of Things era* [9]. Academia researchers have widely studied these changes last years and coined more notions: *Internet of Services* (IoS) and *Web of Services* (WoS). Even though these terms look very similar, they have noticeable distinctions: they enhance, overlap and supplement the original IoT concept. We summarised the main notions used in the article in the Table 1.

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Table 1. Main definitions used in paper

N	Notion	Definition	Source
1	Smart thing / smart object	Objects that are called *smart* carry chunks of application logic that let them make sense of their local situation, intercommunicate and interact with human users via IP protocol.	Kortuem [15]
2	Internet of Things (IoT)	the worldwide network of interconnected objects uniquely addressable based on standard communication protocols.	RFID group [12]
3	Internet of Services (IoS)	the global infrastructure that uses the Internet as a medium for offering and selling services - tradable goods. It represents a model of IoT (self-) organization.	[6], [13], [22]
4	Web of Services (WoS)	the network of interconnected services	[6,13]
5	Social Web of Services (SWoS)	The network of shared services by people and devices via social networks	[6,13]

The main goal of our research is to check how the raising number of internet connected devices influence users. We do it providing and testing a simulation model of SWoS as a reasoning tool for enhancing IoT business models. Firstly, we analyse an existing benchmark of IoT business model through the prism of Osterwalder Canvas framework [18] (chapter 2), apply Agent based modelling simulation (chapter 3) and describe practical application of models (chapter 4).

2. The raise of things

From its foundation, the Internet is constantly improving to be more and more personalized especially during the last two years. Online environment is already about to aggregate each aspect of individual's everyday life, for example, controlled via mobile device. Business in its turn, goes digital as well: virtual workplaces and processes, digital customers and digital "Things". The whole picture is seen as a digital "Ecosystem", where enterprises are connected with its suppliers, distributors and customers in a common digital network. Making business in such Ecosystems is more profitable for companies due to economies of scale, as they are no longer acting as individual corporate entities. Accenture Technology Vision 2015 names this trend "We-Economy" [1].

These concepts lead appearance of the new business models [6,13]. For instance, by monitoring of IoT products lifecycle, companies are able to sell devices directly to the customer at the very moment when such need occurs. By embedding the IoT into social networks and providing mobile and ubiquitous access to its services, companies improve their predictive analytics. Meanwhile Cloud technologies play a role of intermediate platform to connect users, "Things" and Enterprises into a digital Ecosystem [11].

2.1. Smart home – a benchmark of Smart Thing business initiatives

The problem of unified control of all smart devices exercised the minds of such market incumbents as Microsoft, Cisco and others, but their projects had little success. However, during CES 2014 conference Samsung[4] presented their new attempt. The developed app for smartphones or TVs (with Android OS, apparently) let people control home appliances, for example heating system or turn the lights on and off when they are not home with three main functions: device control, home view and smart customer interface. Home View, another part of the service, let people check up on their home using appliance cameras. Moreover, a customer service component alerts people when their appliances need replacing or servicing - something manufacturers would clearly enjoy.

A dedicated Smart Home software protocol (SHP) connects the related devices (refrigerators, washers and dryers, ranges, microwaves, dishwashers, vacuums, smartphones, TVs, gears, audio systems, cameras, computing devices and LED lighting)) and opens access for other vendors, if they choose to get on board. The company plans to eventually expand the Smart Home service to cover home-energy, secure home access, health care, and "eco home applications" through the partnerships with third-party service providers.

There is no detailed information on how exactly operates their platform, and we suppose that all third-parties devices could be included into this app only via agreements with Samsung. The business model of its service is shown on (Fig.1):

[4] Leading Korean company is a major manufacturer of home appliances like washing machines and refrigerators, not to mention smartphones

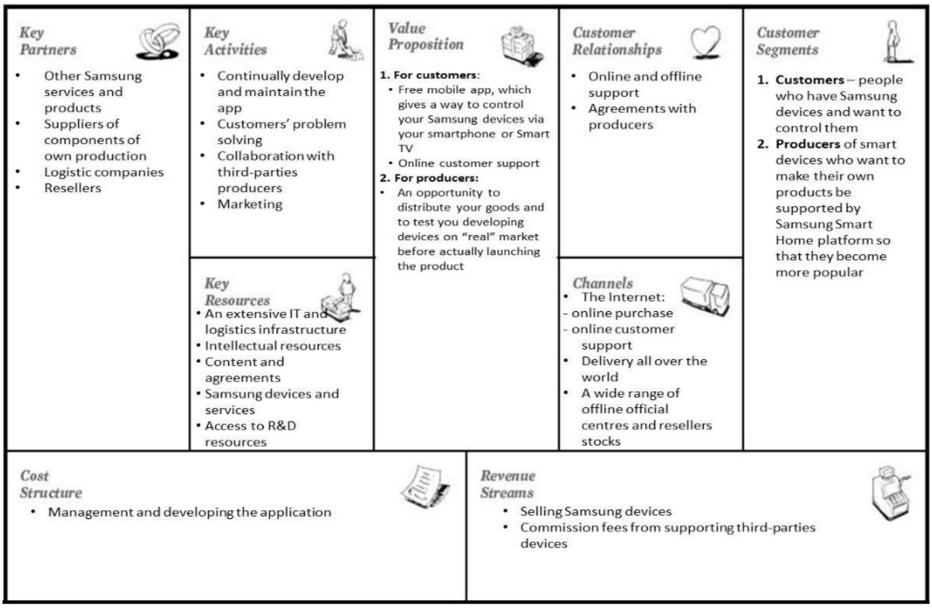

Figure 1. IoT influenced Smart Home Business model

For today, the main limitation for new market players is the range of supported devices and their availability. It is crucially important to work with the most popular and affordable smart devices in order to sweep the market. The biggest competition today is on US market, where there are several competitors and maximal share of iOS devices than in other countries [6]. At the same time, in other countries, Samsung has more power, because the accessibility of its competitors' devices is limited while Samsung products are readily available. However, there is still an opportunity to beat the electronic giant, because of the type of supported devices. While Samsung operates with its own appliances, which are rather massive and expensive, it is possible to enter the market with smaller, cheaper and simpler devices like sensors and power outlets offered by SmartThings [24] and Revolv [20].

The market of smart devices control application is still unsaturated, which leaves an opportunity for new players. There are also several companies, which provide means of communicating to any service via an encrypted P2P connection (Weaved) [25] or different services for developers (Microsoft Home OS and others). However, these three described company are the main pretenders for the unified method of controlling smart devices.

What happens when the number of smart things connected to Smart Home and mother IoT-influenced business models will emerge? How that will affect human behaviour patterns?

To investigate that in the next chapter we use Agent based modelling (ABM).

3. Agent based model simulation

3.1. Agents

ABM simulation is a perfect solution for scrutinizing the aspects of complex systems, which comprise interacting agents. Bonabeau [3] highlighted three main benefits of this approach: it captures emerged phenomena, has a natural-language description and flexibility. What is more, ABM models could be classified depending on their purposes and modelling approach by Borshchev [5]. In our research we used simulation model to track the execution through the discrete states, analyze dynamics and interactions within the algorithm suggested.

According to Macal and North [17], an agent should possess the following patterns:

- Rules to define agent behavior and decision-making
- Protocols to communicate with other agents within the system
- Have autonomous and self-directing functionality
- Be goal-oriented

Taking to consideration these patterns, we have highlighted two types of agents in the model:

Type 1: a Human

Type 2: a Smart Thing (ST) - any electronic gadget with acting scripts, connected to the Internet

As we proceeded with individual agent behavioural rules, the model could be classified as a micro level simulation [4]. Both types of agents have their own attributes in order to trigger behavioural patterns within current simulation process algorithm. Epstein [7] found out that the understanding of social interactions lies in a deep process analytics from which these interactions arise. In order to scrutinize the simulation's results we found out 3 potential outcomes:

1. Smart Things interaction is able to shape a *fully* viral behavioral trend under the suggested default algorithm conditions.
2. Smart Things interaction is able to shape a *partly* viral behavioral trend under the suggested default algorithm conditions.
3. Smart Things interaction, supported with human social effects *is not able* to shape a behavioral trend under the suggested default algorithm conditions.

We have modelled the interaction between Human and ST according to the subjective and average resource requirement. Resource Requirement (RR) is random and specific to each Human agent numeric value, which shows optimal outcome of the Resource usage for concrete Human agent. Either it could be subjective for the concrete Human with individual machine settings or Human agent can accept a requirement trade off, offered by the ST, and receive Average RR with default machine settings (Fig.2).

According to the model (Fig.1), it takes more time for Human to use Resource and get subjective RR (i.e. making choice, machine tune-up, etc.), than to use default setting with average RR suggested by Smart Thing. This motivates Human for insignificant N% RR tradeoff. In case the current average RR differs by less than N% from the subjective RR, Human will use default average value instead of subjective one.

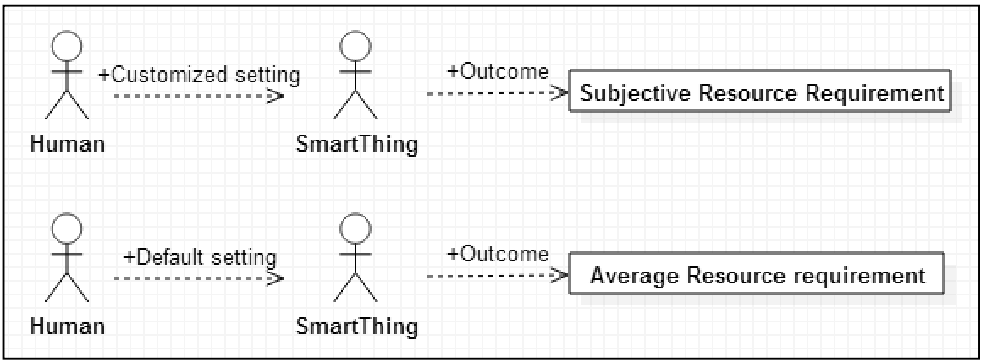

Figure 2. UML visualization of Smart Thing simulation

3.2. ABM description

We have pre-defined a list of conditions before simulation:

1. We assume that one Human has one Smart Thing
2. Humans interact with each other according to the simple random social graph
3. Smart Things are all connected into a one single net, so they can calculate the average RR.
4. Social nature of Human agents influences on their decisions (Once three of four socially connected agents start using the average RR mode, the fourth Human will switch to this mode as well, no matter what the trade-off percentage is.)

Out of respect to the visual aspects, we did a simulation using random social network of 20 Human agents, using their 20 Smart Things (ST). Relations quantities between Humans were randomly generated from 6 to 8 for each agent, representing a social graph (Fig.3, 4). ST were interconnected into a single network.

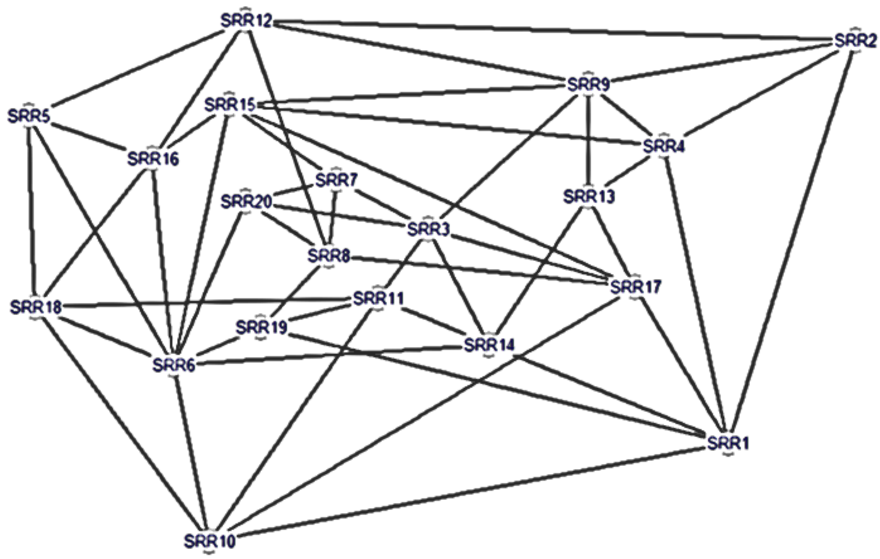

Figure 3. Social graph for Human agents

This model requires several stages of simulation:

1. On the first stage, all the humans have subjective RR (SRR) mode and randomly get their value from 1 to 100. Smart Things, interconnected in the net, calculate the average value of RR. We assume that the number of agents during the simulation is constant.

2. After that, STs choose Humans with N% difference between subjective and average RR to make an trade off offer (Due to the sample size, trade-off percentage was set as 20%). These Humans choose the average RR and will use it on further stages.

3. At the beginning of the second stage, each Human agent checks if any three of his social friends switched to the average RR. In this case, this agent switches as well. Then, Humans use their Resources according to the chosen RR mode. After that, SmartThings calculate the new average RR and start looking for the new humans with possibility of 20% trade-off.

4. On the further stages, the cycle repeats.

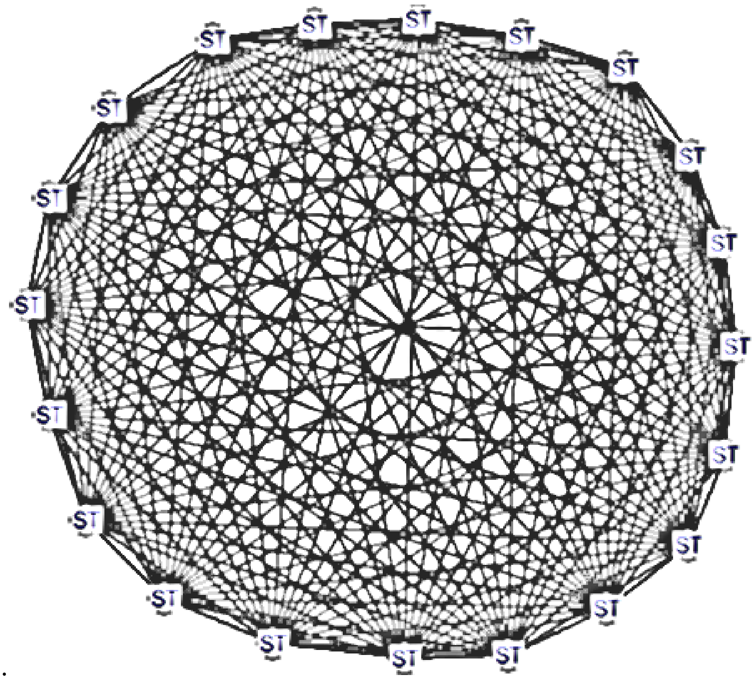

Figure 4. Social graph for ST agents

3.3. Simulation result

In our simulation, different factors were evaluated coherently one by one to define the extent of trend virality. These factors are trade off percentage level, number of social nets per agent, value corridor for randomly generated subjective RR.

Each factor was divided into three value corridors, meanwhile other factors' values were fixed. The most effective way to create a fully viral trend appeared to be agent trade off percentage level. It signifies that the more flexible decisions are made by an agent, the more viral the trend is. Moreover, the number of social nets per agent plays a vital role as well. According to the Appendix 1, fewer nets quantity could decrease trend virality drastically. It took 27 attempts to reach a fully viral trend with 1 to 4 nets amongst 20 agents. Finally, value corridor for subjective RR describes dispersion of agents' preferences. It is easier to reach a fully viral trend when Humans have similar preferences for resource requirement.

However, depending on the sample size, number of social relations and SRR limitations, the trend may occur to be partially viral. In this case, not all of the Human agents will switch to the AVG RR mode. It is proved by the number of simulation attempts, which were done until fully trend were achieved and all agents were switched.

Detail representation of simulation No.5 (see Appendix 1) is shown on the Figure 5. Vertices of the graph are named according to the mask XXAVGYY, where:

XX – is the number of simulation stage, on which agent switched his mode,

AVG – average value for RR,

YY – ID of an agent, from 1 to 20.

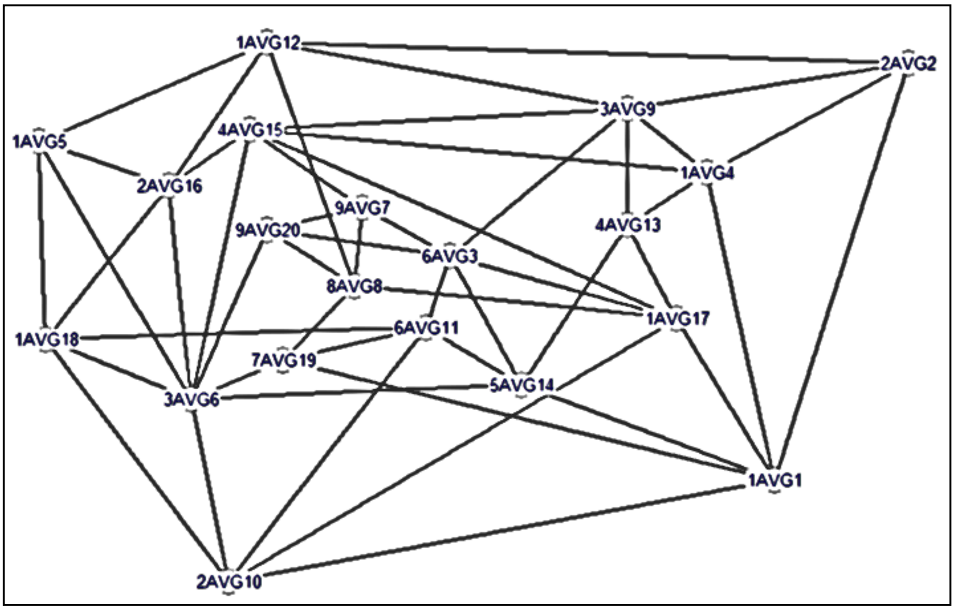

Figure 5. Representation of Smart Thing simulation

Depending on the number of social relations between the Humans and their quantity, the simulation leads to strengthening the trend. In our case, all the Human agents were influenced by the ST proposal during *the fourth attempt*. On the larger samples, ST proposals may not be that influential.

Overall, the SmartThings, connected to the IoT, **are able to change** patterns of Human behavior (see Fig.6).

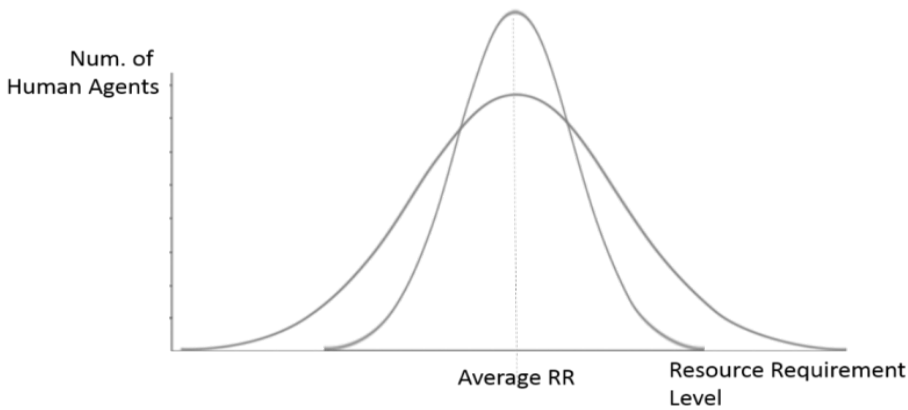

Figure 6. Representation of Smart Thing simulation

Overall, we can conclude that that under the given simulation conditions and agents quantity, two different types of trend were set: *fully viral trend* (all the agents switched their mode) and *partly viral* trend. This means that options 1 and 2 are observed within given simulation conditions. Absolutely viral trend (achieved at the first attempt) was reached with the following simulation conditions:

1. Either trade off percentage level for subjective RR was set at abs. 50% from the current stage average RR level,

2. Or each Human agent was acquainted with 40%-60% of other agents within the whole net,

3. Or scatter of random subjective RR was narrowed to 30%-70% value corridor.

Lower levels of presented conditions lead to the option 2 - partly viral trend. Option 3 - was not detected under given simulation conditions.

3.4. Outcomes

This IoT ABM simulation is good example of slight manipulation on the trends usage through SmartThings' mode setting. Companies can influence these trends by controlling the IoT networks and setting default modes for their smart products and, as a result, sell advanced settings for SmartThings separately. This business model is very similar to nowadays concept of InApp Purchases (IAP) and paid Download Content (DLC) embedded in numerous mobile applications and computer games. This enhancement allows setting a selling price at the lower level and compensate costs by offering IAP, and paid DLC.

4. Concept development and further research

After this work was presented in Sydney DataCom iThings 2015, we received multiple questions where it could be applied except prediction analysis. There is an obvious area – novel process management methodologies considering agents within social web of things.

Subject-oriented Business Process Management (S-BPM) is a relatively new approach for the overall handling of work procedures in organizations from analysis to IT-based execution including cognitive approach [10]. It focuses on the acting entities in processes (people, software, information systems, services, etc.) and their interactions to achieve the process goal. The explicit stakeholder and communication orientation makes it a promising candidate to overcome major drawbacks of traditional BPM as there are deviations of lived processes from their specification (model-reality divide), giving away opportunities for improvement proposed by employees (lost innovation) and slow adaption of organization and IT to changing requirements. With its easy-to-understand and easy-to-use notation based on the Subject–Predicate–Object scheme of natural language, S-BPM facilitates semantic and organizational integration of people in the design of their work procedures. On the other hand, a clear formal semantic behind the graphical notation allows automatic code generation for workflow execution at runtime. Hence, stakeholders can instantly test the models they created and iteratively improve and complete them until they are considered ready for going live and being executed by a workflow engine. This leads to seamless roundtrip engineering based on a common understanding of both business and IT people and can significantly increase organizational agility. S-BPM is not just another modelling language but also a comprehensive methodology spanning the whole business process management life cycle. It suggests a paradigm shift from the traditional control flow-based view to a stakeholder and communication-oriented view on business processes. Subjects represent the active entities in a process and behave in a certain way to accomplish the goal. Their behaviour includes exchanging messages and performing activities on business objects. Hence, a subject-oriented specification of a process follows the standard sentence semantics of natural language consisting of subject, predicate and object. However, S-BPM is a successfully implemented for business process management it is strongly required to have agent based model simulation.

In this regard, it is necessary first to arrange simulation in order to understand how our smart things will act as agents, become independent subjects in one process, and object in another process. Furthermore, it is required to create an integration platform between IoT vendors and data consumers.

5. Conclusion

The developed business model of Social Web of Services combines the idea of common social web and usual service selling, increase the quantity of revenue streams and enhance usual suggested ways of controlling smart devices. It may be the transition way to full Web of Services and it can increase people's way of living by creating “smarter world”.

Provided ABM simulation showed that companies might manipulate human behavioural patterns through ST cooperation and social effects. As a result, there are required usage setting trend could be created. This leads to the main enhancement of the developed business model of Social Web of Services. A number of revenue streams is increased: enterprise is able to sell additional settings as paid In-Machine Purchase or Download content (DLC) where customer relationships are individualized due to subjective preferences.

Information security, information privacy and legitimacy are obstacles that we need to avoid on the way of concept realization. We are sure, that the question of systematic resilience should be the first thing solved before launching the platform. Moreover, we recommend the ownership to be shared not only with private companies, but also with government officials, and perhaps, while the service is international, its localizations in different countries should be separated in order to protect users from different restrictions of the local government.

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The paper is an extended version of the paper presented at the International Conference on Big Data Intelligence and Computing (DataCom 2015), Chengdu, China, December 19-21, 2015

Appendix

Table 2. Aggregated examples of ABM simulation result.

No.	Attempts till fully viral trend achieved	Simulati on stages	Agents switched	Trade off %	Social Nets num.	SUBJECTI VE RR Value Corridor
1	3	8	20	**30**	1-4	1-100
2	4	7	20	**40**	1-4	1-100
3	1	3	20	**50**	1-4	1-100
4	27	8	20	20	**1-4**	1-100
5	4	9	20	20	**4-8**	1-100
6	1	4	20	20	**8-12**	1-100
7	14	6	20	20	1-4	**10-90**
8	7	7	20	20	1-4	**20-80**
9	1	3	20	20	1-4	**30-70**