An Approach to Investigating Socio-economic Tussles Arising from Building the Future Internet

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Abstract. With evolution of the Internet from a controlled research network to a worldwide social and economic platform, the initial assumptions regarding stakeholder cooperative behaviour are no longer valid. Conflicts have emerged in situations where there are opposing interests. Previous work in the literature has termed these conflicts tussles. This article presents the research of the SESERV project, which develops a methodology to investigate such tussles and is carrying out a survey of tussles identified within the research projects funded under the Future Networks topic of the FP7. Selected tussles covering both social and economic aspects are analysed also in this article.

Keywords: Future Internet Socio-Economics, Incentives, Design Principles, Tussles, Methodology

1 Introduction

The Internet has already long since moved from the original research-driven network of networks into a highly innovative, highly competitive marketplace for applications, services, and content. Accordingly, different stakeholders in the Internet space have developed a wide range of on-line business models to enable sustainable electronic business. Furthermore, the Internet is increasingly pervading society [3]. Wide-spread access to the Internet via mobile devices, an ever-growing number of broadband users world-wide, lower entry barriers for non-technical users to become content and service providers, and trends like Internet-of-Things, or the success of Cloud services, provide indicators of the high significance of the Internet today. Hence, social and economic impacts of innovations in the future Internet space can be reasonably expected to increase in importance. Thus, since the future Internet can be expected to be characterized by an ever larger socio-economic impact, a thorough investigation into socio-economic tussle analysis becomes highly critical [9].
The term tussle was introduced by Clark et al. [5] as a process reflecting the competitive behaviour of different stakeholders involved in building and using the

Internet. That is, a tussle is a process in which each stakeholder has particular self-interests, but which are in conflict with the self-interests of other stakeholders. Following these interests results in actions – and inter-actions between and among stakeholders. When stakeholder interests conflict, inter-actions usually lead to contention. Reasons for tussles to arise are manifold. Overlay traffic management and routing decisions between autonomous systems [11] and mobile network convergence [10] constitute only two representative examples for typical tussle spaces.

The main argument for focusing on tussles in relation to socio-economic impact of the future Internet is in the number of observed stakeholders in the current Internet and their interests. Clark et al. speak of tussles on the Internet as of today. They argue [5] that "*[t]here are, and have been for some time, important and powerful players that make up the Internet milieu with interests directly at odds with each other.*" With the ongoing success of the Internet and with the assumption of a future Internet being a competitive marketplace with a growing number of both users and service providers, tussle analysis becomes an important approach to assess the impact of stakeholder behaviour.

This paper proposes a generic methodology for identifying and assessing socio-economic tussles in highly-dynamic and large systems, such as the current and future Internet. In order to help an analyst during the tussle identification task, we provide several examples of tussles and their mapping to four abstract tussle patterns we distinguished. Furthermore, we present a survey of tussles and the way those have been addressed by several FP7 projects.

SSM (Soft Systems Methodology) proposed by Checkland [4] and CRAMM (CCTA Risk Analysis and Management Method) [7] have similar objectives to our methodology. The former, being extensively used when introducing new information systems into organizations, suggests an iterative approach to studying complex and problematic real-world situations (called systems) and evaluating candidate solutions. The latter one aims at identifying and quantifying security risks in organizations. The situations analysed by the aforementioned methodologies are often associated with certain kinds of tussles. However both of them are quite restrictive in the way evaluation of situations is performed, suggesting specific qualitative methods. On the other hand, the proposed tussle analysis methodology provides a higher-level approach allowing and/or complementing the application of a wide range of techniques (both qualitative and quantitative). For example, microeconomic analysis can be applied, which uses mathematical models aiming to understand the behaviour of single agents, as part of a community, who selfishly seek to maximise some quantifiable measure of well-being, subject to restrictions imposed by the environment and the actions of others [6]. Similarly, game-theoretic models that aim at finding and evaluating all possible equilibrium outcomes when a set of interdependent decision makers interact with each other is another candidate method. In this way, one can derive what the possible equilibrium points are, under what circumstances these are reached, and compare different protocols and the tussles enabled thereby with respect to a common metric. Such a metric can be social welfare or 'Price of Anarchy' [12], the ratio of the worst case Nash equilibrium to the social optimum.

2 A Methodology For Identifying And Assessing Tussles

The *Design for Tussle* goal is considered to be a normal evolution of Internet design goals to reflect the changes in Internet usage. However, providing a systematic approach for identifying both existing and future tussles and assessing their importance has received little attention by researchers. Furthermore it could help to better understand the hierarchy of tussles that exists which can be valuable during assessment. Such a methodology should be an algorithm that can be applied to any Internet functionality and audience. This would support policy-makers (like a standardization body) to prepare their agenda by addressing critical issues first, or protocol designers so that functionality is future-proof. For example the latter could apply this methodology before and after protocol introduction in order to estimate the adoptability and other possible consequences.

The proposed methodology is composed of three steps and can be executed recursively. Each iteration broadens the analysis as more stakeholders, tussles, etc. are included, and the analyst should decide when to stop based on her goals. It is important to note that for each step of this procedure many techniques could be available for completing this task, but not all of them may be perfectly suitable.

The proposed methodology is the following:

1. Identify stakeholders for a specific functionality. Usually this functionality is directly related to a protocol or an application.
2. Identify tussles among stakeholders and their relationship (i.e. are some of them orthogonal or not?).
3. For each tussle:
   a. Identify how control is distributed across stakeholders (is balanced or not?)
   b. If control is imbalanced assess the impact.
   c. Identify whether a subset of disadvantaged stakeholders could use other protocols/tricks to gain more control, which has a negative impact on other functionalities (tussle spill-over). For each new protocol/trick, apply the methodology again.

For all steps of this methodology except from 3b, personal observation and questionnaires would be the most straightforward way to go. Impact assessment (3b) could be performed by mathematical models for assessing risk or utility, as well as providing benchmarks like the price of anarchy ratio. Ideally a single metric should be used so that results for each tussle are comparable. Note that the assessment of each side-effect (step 3c) is performed in the next iteration. Identifying side-effects is a way to better understand the relationship among tussles. In most cases there is a cause and effect connection between two or more tussles, which produces a hierarchical structure and can be valuable during assessment of the different root tussles.

In the following we will apply the above methodology in the case of congestion control with TCP, assuming the analyst stops at the second iteration.

In the first iteration, congestion control mainly affects heavy users (HUs), interactive users (IUs) and ISPs. We could identify two tussles that are closely related; a) contention among HUs and IUs for bandwidth on congested links and b) contention among ISPs and HUs since the aggressive behaviour of the latter has a negative effect on IUs and provision of other services. Assuming that the ISP's network remains the same, control in both tussles is considered biased. An IU gets K1 bps by opening a single TCP connection, while an HU opens N TCP connections and gets K2 bps (where K1<<K2), regardless of their utility on instantaneous bandwidth. Similarly, only a HU controls how many TCP connections will be active, since the ISP has no means to correlate connections with applications. In order to assess the impact of the first tussle, an analyst could measure social welfare loss or calculate the price of anarchy ratio, noticing that the latter can be very large due to starvation of IUs. On the other hand, risk assessment techniques seem more relevant for the second tussle since high congestion can have an impact on ISP's plans to offer other real-time services. Identifying possible spill-over effects for the tussle among HUs and IUs we could mention the possibility for developers of interactive applications or ASPs (Application Service Providers) to adopt more aggressive techniques, resulting in greater contention. In the second tussle, an ISP could employ middle-boxes and perform traffic shaping based on port number, which has a negative impact on QoS-aware applications of third-party ASPs.

In the second iteration we will concentrate on the network neutrality issue that is considered a side-effect of traffic-shaping (but not the only reason). In this case, the set of stakeholders is extended to include ASPs as well. The new tussle involves ISPs and ASPs (i.e. VoIP providers), since the traffic of the latter is being throttled by middle-boxes (either on purpose or not). Again, control is imbalanced; only ISPs can configure the middle-boxes since there is no API (Application Programming Interface) for ASPs to affect how their traffic will be handled. ASPs and HUs can employ protocol obfuscation techniques and ISPs can reply by more aggressive traffic shaping, resulting in an endless arms' race. Risk assessment techniques could be used in this case, as well as models for estimating social welfare loss. A side-effect of this tussle is innovation discouragement since new applications are harder to become widely known, which may result in regulatory intervention.

3 A Taxonomy of Socio-Economic Tussles

We have identified an initial set of four tussle patterns that include contention, repurposing, responsibility and control (see Figure 1). Based on the context, the reverse pattern may also be present. The characteristics of each pattern can be seen in many current and future Internet scenarios. Each pattern looks at relationships between consumers and suppliers and how conflicts of interest can emerge through technical innovations. The dynamics of a relationship over time is important, as interests, values and technologies change. By classifying tussle patterns we envisage the development of generalised technical solutions that can be applied to multiple domains and thus act as a guide in performing the second step of the proposed methodology for identifying and assessing tussles. It is important to note that the roles 'consumer' and 'provider' are context specific, and an individual stakeholder can be a resource consumer in one tussle, but a provider of a resource in another. For instance, while individual internet users are typically consumers, when they are creating data that a business would like to sell, with or without their knowledge and consent, they are 'providers' of the resource in such a scenario.

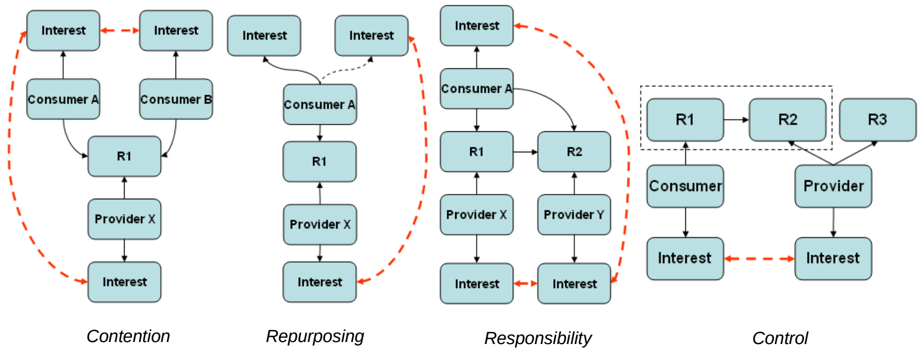

Figure 1: The Initial Set of Tussle Patterns

The initial set of tussle patterns is described below:

- **Contention**: two or more consumers (A and B) using a single resource (R1) from a provider (X) for the same or different interests. The tussle exists either between consumer interests due to the scarcity of resource, or among a consumer and the provider due to the impact on a provider's ability to exploit the resource. The role of the consumer may be played by an end-user or even a provider that receives services at the wholesale level. In the reverse case, two providers may compete for a resource owned by a single consumer. Instances of this tussle pattern have their roots in economics and thus are typically resolved through the process of economic equilibrium or through regulation when an interest becomes a citizen's right. Examples include cloud resources utilization like bandwidth of bottleneck links.

- **Repurposing**: a consumer (A) wants to use a resource (R1) from a provider (X) for an interest not envisaged by (X). The tussle exists between consumer and provider if A's new interest utilises R1 in unforeseen ways that affects X's ability to deliver R1 sustainability, and/or the value A derives from their new interest fair exceeds that gained by X. The situation often results in X restricting the capabilities of resources. Examples of economic tussles include sharing of copy-righted files (i.e. music) and selling of personal information.

- **Responsibility**: a consumer (A) uses a resource (R1) from provider (X) and resource (R2) from provider (Y) to fulfill an interest that is not acceptable to provider (Y). The tussle exists between providers as it is not in X's interest to defend Y's interests. The situation is difficult to resolve as acceptance of responsibility has a cost, which when not aligned with a business objective is difficult to incentivise. Example includes distribution of rights protected content.

- **Control**: a consumer – or provider – (X) uses a resource (R1) but relies on provider (Y) in order for the service to be completed. Provider (Y) can use either resource (R2) or (R3), but chooses R2 that is different from the one provider (X) prefers. This tussle pattern arises because each provider makes decisions following different policies and is mostly related to economic objectives. An example of such tussles is attempts by an ISP to restrict how a consumer uses the resource (i.e. not allowing VoIP applications that compete with other complementary services it provides).

3.1 Economic tussles

Economic tussles refer to conflicts between stakeholders, motivated from an expected reward gained (or cost avoided) when acting rationally. These tussles are realized by taking advantage of imbalanced access to necessary information, or uneven control abilities. The latter case stems from protocol features not designed for being used in that way, or were intentionally left out of scope. Economic tussles are mostly related to the scarcity of certain resources that need to be shared. Furthermore, such tussles can occur between collaborating stakeholders due to different policies or, in economic terms, different valuations of the outcome. Tussles can also appear when a stakeholder is being bypassed.

Contention tussles are usually caused by the existence of scarce resources and can be seen as evidence of misalignment between demand and supply in the provisioning of services. A popular example is bandwidth of bottleneck links and radio frequencies shared between users and wireless devices. In the former case, modern transport control protocols perform congestion control without considering the utility of the sender on instantaneous bandwidth or the number of their active connections. This, together with the prevalence of flat pricing schemes, has led to a contention tussle among user types, which economists identify as a 'tragedy of the commons'. Similar contention tussles can take place for other cloud resources as well, such as processing and storage capabilities of servers and networking infrastructure. For example, routing table memory of core Internet routers can be considered a 'public good' that retail ISPs have an incentive to over-consume by performing prefix de-aggregation with Border Gateway Protocol (BGP). Another type of scarce Internet resources is network identifiers, like IPv4 addresses and especially 'Provider Independent' ones that ease network management and avoid ISP lock-in. Sometimes a contention tussle between consumers can have side effects on the owner of the scarce resource, which is an economic entity and must protect its investments. Examples include the deployment of Deep Packet Inspection techniques by ISPs in order to control how bandwidth is allocated across users and services.

Responsibility tussles usually arise when a service contract term is violated and the consumer has economic transactions with multiple providers. This is the case when a set of providers collaborate during service provision with strict requirements, like long-distance phone conversations taking place over Internet. Each provider has partial private information about the problem and no one is willing to take responsibility and the resulting cost. Furthermore, this type of tussle can occur as a side effect to a contention tussle. In the example of file sharing applications, if an ISP deployed middle-boxes and performed traffic shaping then it may have negative impact on the services, and thus, viability of new ASPs.

Control tussles can appear when a pair of entities makes decisions following different policies and conflicting objectives. Examples of such tussles include different policies on routing decisions, for example next-hop selection by ISPs as well as, traffic destination. In the former case, a provider may seek redundancy and reliability asking for a backup path towards a destination, or prefer avoiding specific upstream ISPs. In the latter case, when multiple candidate servers exist a consumer may prefer the one offering better QoS, while a provider selects the server that minimizes her cost (this is possible if provider operates a local DNS service).

3.2 Social tussles

What do we mean when we discuss social tussles? At the most basic level, these tussles represent issues that arise as a result of a disconnect between the technical affordances of the network and the interests of regulators, business and individuals at the micro level and societal values and social goods at the macro level. We can identify some social tussles that arise as a result of how individuals interact with each other and with technology, based on their roles, identities, and psychology.

Repurposing tussles occur in regards the privacy of user communication data between users, ISPs, service providers and regulators. The users (i.e. social actors) have a desire that networks are trustworthy and private [2]. The privacy of communications is based on democratic ideals, that persons should be secure from unwarranted surveillance. However, the issue turns into a tussle over the very definition of what constitutes unwarranted surveillance, and when surveillance may be warranted in ways that individual users are willing to forego their privacy concerns in the interest of broader societal concerns. Governments frequently argue that in order to protect national security, they must be given access to network communication data. ISPs and other companies such as Google, and Amazon, have increasingly been able to monetize their data on user transaction data and personal data. Google is able to feed advertisements based on past searching and browsing habits, and Amazon is able to make recommendations based on viewing and purchasing habits. These uses of user data are largely unregulated. And, in many cases, users have proved willing to give up some of their privacy in exchange for the economic benefit of better deals that can come from targeted advertising. However, for users who wish to opt out of such systems, the mechanisms for doing so are often less than clear, since the owners of the system prefer to keep people in, rather than easily let them out.

Responsibility tussles occur with ISPs that often inhabit a middle ground – they are the bodies with direct access to the data, but are simply businesses, trying to make a profit. ISPs, however, are often placed in the uncomfortable position of trying to negotiate a balance between their users' expectations of privacy (which, if breached, could cause them to take their business elsewhere), the potential profits to be made from monitoring and monetizing the communication of their users, and the demands of government bodies to be able to monitor the networks for illegal or unwanted activities.

Control tussles in a social context relate to digital citizenship and understanding the balance between individual and corporate rights and responsibilities, and how such a balance can be achieved through accountability and enforceable consequences (e.g. loss of privileges), preferably in the future Internet but also linked to the real world. This is a very tough problem and relates to those promoting principles of open society and those wishing to maintain confidential communication. Is Wikileaks right or wrong to do what it does? If it is wrong what sanctions would be appropriate, and how could the future Internet implement them? Bearing in mind that the Internet can't just assume Western values (if we could agree even within Europe what that means). And that it should respect national sovereignty. Such a tussle of control would need to be assessed by philosophers and politicians as well as security and trust experts.

4 Survey of Work on Social and Economic tussles as highlighted in FP7 projects

In this section, we look at specific projects in the FP7 Future Networks project portfolio, and discuss the socio-economic tussles related to them.

The Trilogy project [16] studied extensively the 'Contention' tussle among users as well as among an ISP and its customers, due to the aggressive behaviour of popular file-sharing applications. On the one hand it proposed two protocols and a novel congestion control algorithm that gives the right incentives to users of bandwidth intensive applications. Re-ECN protocol makes senders accountable for the congestion they cause. It requires a sender to inform the network about the congestion that each packet is expected to cause, otherwise the packet will be dropped with high probability before reaching its destination. MPTCP is a new multipath transport protocol that carefully couples the congestion control of multiple sub-paths so that ISPs' resources are shared between users in a fairer manner. This is achieved by configuring MPTCP so that it acts less aggressive than TCP when the latter flows experience congestion, and more aggressive otherwise. Furthermore, the adoption of several protocols (i.e MPTCP, LISP) and pricing schemes (based on traffic volume and congestion volume) has been studied as a control tussle among providers.

The Trilogy project also studied the social tussles surrounding 'phishing', the attempt to acquire sensitive personal data of end-users by masquerading as a trustworthy entity, as a reverse 'contention' tussle among two website owners (the 'consumers'). The tussle is being played out in the routing domain; the fraudulent one advertises more specific BGP prefixes so that ISPs update the entries in their routing tables (the resource) and route end-user requests to the fake website instead of the real one. This situation has been shown to be a real problem due to the incentives of ISPs to increase their revenues by attracting traffic, but no mechanism has been suggested to deal with this security problem and the fears that it raises among end-users. There is a special social concern regarding vulnerable populations such as the elderly, who are often considered to be easy targets for such phishing attempts.

The ETICS project (Economics and Technologies for Inter-Carrier Services) [8] studies a 'repurposing' tussle arising when an ISP (the 'provider') requests a share of an ASP's revenues (the 'consumer') due to its higher investment risks and operational costs. ETICS proposes technical solutions and economic mechanisms that will allow network providers to offer inter-domain QoS assurance and obtain higher bargaining power during negotiations for service terms (i.e. pricing). The need for collaboration among ISPs gives rise to a 'control' tussle and a 'responsibility' tussle in case of contract term violation.

The SmoothIT project (Simple Economic Management Approaches of Overlay Traffic in Heterogeneous Internet Topologies) studies the 'control' tussle that arises between ISPs and ASPs with respect to the routing decisions of each party. An ASP or peer-to-peer (P2P) application may employ advanced probing techniques for estimating the performance on each path and select the path (or destination) that maximizes its utility. At the same time an ISP performs traffic engineering without being able to predict how ASPs will react. This results to an endless loop of selfish actions that increases the cost of ISPs and limits performance gains of ASPs. To this end, an incentive-based approach was developed, referred to as the Economic Traffic Management (ETM). ETM offers better coordination among the aforementioned players that is mutually beneficial for all the aforementioned players [15].

The development and investigation of In-Network Management mechanisms was a novel paradigm to manage networks according to the 4WARD project [1]. Since it is based on a lean architecture to operate new services in the Future Internet, the discovery of capabilities and the adaptation of many management operations to current working conditions of a network are major elements in the new approach. Thus, a 'control' tussle arises, where embedded capabilities of networking devices and elements see 'default-on' management functionality, which consist out of autonomous components interacting with each other in the same device and with components in neighbouring devices. This requires device vendors to change their management model and ISPs to enable respective embedded management functionality within their networks.

The MOBITHIN project [13] studies a 'responsibility' tussle between users of wireless services, mobile operators and regulators that has arisen from the social interest to reducing carbon footprint of the ICT sector and the economic incentive to minimize costs. The regulator ('Provider Y' in Figure 1 even though it does not directly contribute a resource) is trying to place limits on energy consumption of both consumers and providers and may introduce penalty fees to those that don't use efficient technologies. Due to economies of scale the thin-client paradigm, where most applications run on a remote server, is considered to achieving energy savings but to the disadvantage of the server provider. However under some assumptions, WiFi hotspots can consume much less energy than UMTS (Universal Mobile Telecommunications System) networks. Thus, responsibility cannot be easily checked. Furthermore, this situation triggers a 'control' tussle between wireless network operators and users of dual-band devices (i.e. WiFi and UMTS) on the technology used to communicate. Next generation networks, where a provider can control which access technology is used by its end-users, could affect the user's ability to derive maximum value from the service.

The SENDORA project [14] identifies a 'contention' tussle based on their own ecosystem design for Sensor Network aided Cognitive Radio technology that utilizes wireless sensor networks to support the coexistence of licensed and unlicensed wireless users in an area. In this case, the spectrum is the resource in contention and the "provider" is the regulator, which is not the owner but the administrator of the resource. Existing mobile operators, TV broadcasters and new operators are the 'consumers' of the resource in contention. The latter is looking to have a slice of the resource in order to develop business whilst the former two are at once trying to block the entry of new entrants to the market and minimize any impact on their existing business. The solution proposed by SENDORA is to build this tussle into their business ecosystem and to design benefits for the incumbent resource consumers (ie mobile operators and TV broadcasters) such as reduced operating costs, superior technology and potentially lucrative spectrum trading. Furthermore, there is a 'repurposing' tussle between a regulator for anti-competitive tactics and the provider. The spectrum can be used for providing a service as well as a barrier-to-entry which is in conflict with the regulator's interest for preventing monopolies.

5 Conclusions

In this paper we proposed a methodology for identifying and assessing tussles that are present in the Internet, or may arise after a protocol or service has been introduced. Although the suitability of such a methodology cannot be easily quantified, we believe it can capture the evolving relationships among stakeholders, and thus tussles, across time. Furthermore, we provide a taxonomy of economic and social tussles to a number of identified patterns and give examples of such tussles and how these are studied by several European research projects under FP7.

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