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

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Abstract. With the evolution of the Internet from a controlled research network to a worldwide social and economic platform, the initial assumptions regarding stakeholder cooperative behavior are no longer valid.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 analyzed 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 the Internet-of-Things or the success of Cloud services, all 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 behavior 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 behavior.

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, the approach presented here provides several examples of tussles, together with their mappings to four abstract tussle patterns. Furthermore, a survey of tussles is also presented 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, which is 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 approach aims at identifying and quantifying security risks in organizations. The situations analyzed by the aforementioned methodologies are often associated with certain kinds of tussles. However 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 behavior of single agents, as part of a community, who selfishly seek to maximize 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 the "Price of Anarchy" [12], i.e., the ratio of the worst case Nash equilibrium to the social optimum.

The remaining of this article is organized as follows. In Section 2 we describe the proposed methodology for identifying and analyzing socio-economic tussles in the

Future Internet. In Section 3 we provide a classification of tussles according to stakeholders' interests into social and economic ones, which can be used as a reference point when applying this methodology. In Section 4 we provide examples of existing and potential tussles being studied by several FP7 research projects and we conclude in Section 5 by outlining our future work.

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. This paradigm shift should be reflected in new attempts for building the Future Internet. However, identifying both existing and future socio-economic tussles, understanding their relationship, assessing their importance and making informed technical decisions can be very complicated and costly, requiring a multi-disciplinary approach to grasp the potential benefits and consequences.

Providing a systematic approach for this task has received little attention by Future Internet researchers. Such a methodology should be a step-by-step procedure that can be applied to any Internet functionality, acting as a guide for making sure that all important factors are considered when making technology decisions. This would support policy-makers (such as standardization bodies) 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 effects, both positive and negative ones, for the Future Internet.

The proposed methodology is composed of three steps and can be executed recursively, allowing for more stakeholders, tussles, etc. to be included in the analysis. It is out of the article's scope to suggest where the borderline for the analysis should be drawn, as this choice depends on subjective factors like the goals of the analysts and their views on the criticality of each research issue. Nevertheless, this requires all steps of the methodology to be performed in a justifiable way; following a code of research ethics (e.g. assumptions should be realistic and agreed by all team members). It is also 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. A multidisciplinary team, composed of engineers, economists and social scientists, would allow for suggesting candidate techniques and incorporating useful insights from different domains at each step of the methodology.

The proposed methodology is the following:

1. *Identify all primary stakeholders and their properties for the functionality under investigation.*
2. *Identify tussles among identified stakeholders and their relationship.*
3. *For each tussle:*
   a. Assess the impact to each stakeholder;
   b. Identify potential ways to circumvent and resulting spill-overs. For each new circumventing technique, apply the methodology again.

The first step of the methodology suggests identifying and studying the properties of all important stakeholders affected by a functionality related to a protocol, a service, or an application instance. The outcome of this step is a set of stakeholders and attributes such as their population, social context (age, entity type, etc.), technology literacy and expectations, openness to risk and innovation. Furthermore, it should be studied whether and how these attributes, as well as the relative influence across stakeholders, change over time.

The next step aims at identifying conflicts among the set of stakeholders and their relationship. In performing the first part of this step the analyst could find particularly useful to check whether any tussle pattern described in the next section can be instantiated. After the identification task the analyst should check for potential dependencies among the tussles, which can be useful in understanding how these are interrelated (for example are some of them orthogonal, or have a cause-and-effect relationship?).

The third step of the methodology proposes to estimate the impact of each tussle from the perspective of each stakeholder. In the ideal scenario a tussle outcome will affect all stakeholders in a non-negative way and no one will seek to deviate; thus an equilibrium point has been reached. Usually this is a result of balanced control across stakeholders, which means that the protocols implementing this functionality follow the Design for Choice design principle [5]. Such protocols allow for conflict resolution at run-time, when the technology under investigation is being used. However there will be cases where some – or all – stakeholders are not satisfied by the tussle outcome and have the incentive to take advantage of the functionality provided, or employ other functionalities (protocols/tricks) to increase their socio-economic welfare triggering a tussle spill-over. Tussle spill-overs can have unpredictable effects and are considered to be a sign of flawed architectural design [9]. If a tussle spill-over can occur then another iteration of the methodology should be performed for the enabling functionality, broadening the scope of the analysis.

Of course, one difficult aspect to these approaches is acquiring the empirical evidence from which one can draw inferences about stakeholders and tussles. For all steps of this methodology except for 3a, system modeling by using use-case scenarios and questionnaires would be the most straightforward way to go. However, in complex systems with multiple stakeholders, multiple quantitative and qualitative sources of evidence may be required to better understand the actual and potential tussles. Thus, one can think of the tussle approach outlined here as just one of a set of tools necessary to identify, clarify, and help in resolving existing and emergent tussles. For instance, impact assessment (3a) 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 3b) is performed in the next iteration.

In the following the methodology above is applied in case of congestion control with TCP, assuming the analyst stops at the third iteration.

In the first iteration, congestion control mainly affects heavy users (HUs), interactive users (IUs) and ISPs. Two tussles have been identified, which are closely related: (a) contention among HUs and IUs for bandwidth on congested links and (b) contention among ISPs and HUs since the aggressive behavior 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 it can be mentioned that 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 the focus laid will be 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 (e.g. 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.

In the third iteration it will be assumed that the policy-maker (a new stakeholder) decides to intervene, with the important advantage of proactively seeking the socially optimum solution. The regulator's decision will redistribute control across stakeholders in a balanced way or, in more complex cases, cause new tussles to arise. Since future tussles depend on the regulator's action and the possible set of actions can be large, the regulator should perform an iteration of the methodology for each scenario. Then the policy-maker should select the action with the most favorable properties. In practice, of course, other factors will often intercede and result in actors making less than perfectly rational decisions, but it will be assumed for the sake of argument that the actors are seeking optimum solutions.

3. A Taxonomy of Socio-economic Tussles

Many articles have been published building on Clark's work as applied to specific technical domains [12,13]. However, the extensive range of tussles to be addressed and analyzed by SESERV requires a classification framework for tussles based on abstract tussle patterns.

On the left part of Figure 1 we see a general model for a single tussle. In the model, agents have resources that are used to realize their interests. A tussle occurs when two agents have an interest in a resource that cannot be satisfied for both through the utilization of the resource. On the right part of Figure 1 we see that agents acting selfishly can lead to new tussles (spill-over) that may involve new stakeholders as well. For example, the Tussle I among Actor A and Actor B may trigger the Tussle II involving the same stakeholders, or a Tussle III among Actor B and Actor C. This basic model is extended to identify abstract tussle patterns that can be used to identify and analyze a broad range of tussles from the desired topic space. Each tussle pattern identifies agents, their interests in resources and how conflicts of interests emerge between actors. Each tussle pattern has distinctive characteristics that make them difficult to resolve.

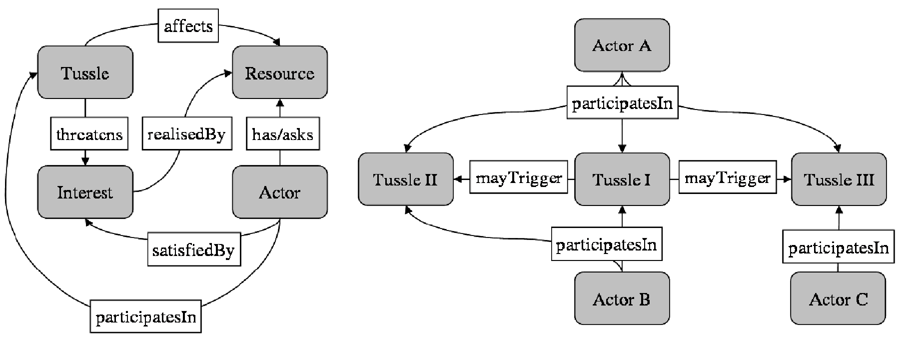

Fig. 1. An ontology for socio-economic tussles

Tussles can be categorized based on their nature as economic and social ones. Economic tussles refer to conflicts between stakeholders, motivated from an expected reward gained (or cost avoided) when using scarce resources rationally, while social tussles refer to conflicts between stakeholders that do not share the same social interests, or that have repercussions into broader society as a result of changes in the technical domain. Tussles related to engineering decisions during design-time are out of article's scope, but we argue that most of them have their roots in economic and social domain. We should note that a single tussle instance could have arisen because a set of stakeholders follow economic objectives and their actions affect the social interests of other stakeholders.

3.1 Tussle Patterns

We have identified an initial set of four tussle patterns that include contention, repurposing, responsibility and control. Figure 2 shows the actors involved in each tussle pattern, and their interests that result in conflict for a set of resources. Dotted arrows represent a conflict among two stakeholders, while a dotted rectangle shows the selected set of resources when at least one stakeholder has the ability to influence the outcome. Based on the context, a reverse tussle 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 provision of a reference point 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. The initial set of tussle patterns is described below.

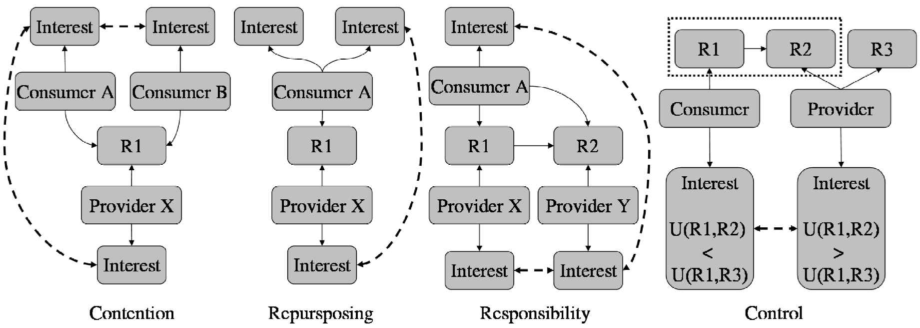

Fig. 2. The Initial Set of Tussle Patterns

The *contention* tussle pattern involves 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 (we refer to this case as the reverse contention tussle). 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. If pricing schemes for such shared resources are not sensitive to the volume consumed then a “tragedy of the commons” can arise.

In the *repurposing* tussle pattern, a consumer A wants to use a resource R1 from a provider X for an interest not acceptable to X. The tussle exists between consumer and provider if A’s new interest utilizes R1 in unforeseen ways that affects X’s ability to deliver R1 sustainably, 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 (e.g. music) and selling of personal information. It is important to note that many innovations in the Internet space have involved repurposing of resources, so identifying this sort of tussle also represents a way to find potential areas of growth and innovation.

In the *responsibility* pattern, 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 copy-righted content.

In the *control* tussle pattern, 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 (e.g. performing deep packet inspection and throttling so that quality of other services is acceptable).

3.2 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.

The remaining tussle patterns are mostly seen in bilateral or multilateral transactions where one party has an information advantage over others; a situation known as "information asymmetry" in the economic theory literature. This imbalance of power can sometimes lead to "market failures", a case where the final outcome is not preferable by any participant. Two well-known effects of information asymmetry are "adverse selection" and "moral hazard".

Adverse selection arises when several providers offer the same service, with possibly different quality features known only to each seller, and the buyer who seeks a high-quality service is prepared to pay on average less than the price he would be willing to pay if he could infer the quality of all candidates and select the most suitable one. But, this lower price would lead some sellers of higher quality services to stop selling (since they do not cover their costs anymore) and thus, in the long term, only low quality services will be available. Similarly, if a service provider were the less informed party, then setting - for example - a low price would increase his risk of being selected by the least profitable customers. This would increase his costs and trigger a rise in prices, making this service less attractive to a number of profitable customers. Eventually this "adverse selection spiral" might, in theory, lead to the collapse of the market. The *repurposing* tussle pattern described above can be associated with the adverse selection issue.

Moral hazard can occur when one party of the transaction cannot (or it is very costly to) infer the actions of the other one and thus the latter one may have the incentive to behave inappropriately. *Responsibility* tussles are related to moral hazard and 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, on the viability of new ASPs, who however cannot safely attribute these effects to the ISP.

Closely related to moral hazard is the "principal-agent problem", where one party - the principal – delegates control to the agent, but their interests are not aligned and thus the latter has the ability and incentive to shirk. The *control* tussle pattern is a principal-agent type of problem, observed when the involved parties have a customer-provider relationship or, in general, when a contract outlines their obligations. For example, 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 ISPs selecting the next hop of user traffic while users selecting the traffic source in their requests. 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 are available, a consumer may prefer the one offering better QoS, while a provider selects the server that minimizes its cost; e.g., this is possible if the provider operates a local DNS service. However, the control pattern includes also cases where there is no contract between the participants and these may have conflicting interests on the possible outcomes. In this last case, information about each other's preferences, possible actions and ability to observe past actions can have significant effect on the outcome, as is the case with the "prisoner's dilemma" game theoretic problem.

Researchers have proposed several methods in order to deal with the above issues. For example, incentive schemes like reputation systems and penalties to promote effort and care are suggested as a countermeasure for moral hazard issues. Similarly, the proposed way for mitigating the effects of adverse selection is for the less informed party to gather more information (called "signaling") and select candidate transaction partners (called "screening") by using, for example, auctions.

3.3 Social Tussles

What does SESERV mean when discussing 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. SESERV can identify 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 to the privacy of user communication data between users, ISPs, service providers and regulators. The users are social actors who have a desire, generally speaking, 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. Furthermore, ISPs and other companies such as Google and Amazon have increasingly been able to monetize their 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 applications of user data as marketing tools 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, for instance, 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). This is a difficult issue, which must be debated and resolved in the real world by policy makers and legal experts. However, these processes tend to be slow to deal with change, particularly when compared to the speed of change in many technological systems such as the Future Internet. In practice, technology that upsets the balance of control is often released and the debates over control and resulting policy changes follow. In some ways, new technology that unbalances existing systems of control can be the impetus and focus of debates that would otherwise be quite dry and difficult to interest politicians and citizens in. This is a very tough problem and relates to those promoting principles of open society and those wishing to maintain confidential communication.

For instance, is Wikileaks right or wrong to distribute leaked documents containing the details of government and corporate communications? Until Wikileaks started releasing real documents of widespread interest, few people were interested in debating the societal risks and values surrounding a platform that could potentially distribute previously secret documents. However, once Wikileaks began distributing documents, millions of people worldwide began to debate these very issues in the media, in seats of government and power, and at the dinner table. Suddenly, questions regarding whether Wikileaks should do this, whether governments and businesses had the right to censor or attack them for doing so, and what role ISPs and service providers such as PayPal have in supplying services to controversial online bodies come to the forefront. If Wikileaks is wrong, what sanctions would be appropriate, and what technical designs would be appropriate to implement them? Conversely, if Wikileaks is right, what technical designs can protect such sites from being attacked by entities inconvenienced or embarrassed by their revelations? The Internet makes this a particularly contentious issue because with the global nature of the Internet one can't just assume Western values (as if it were possible even within Europe to agree to what that means). Where does national sovereignty fit into all of this? 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, SESERV looks 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 behavior 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 multi-path 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 aggressively than TCP when the latter flows experience congestion and more aggressively 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 (e.g. 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 [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 neighboring 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] is related to 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 (who is in charge of allocating and administering how spectrum is being utilized and thus can be seen as “Provider Y” in Figure 2) 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 (e.g. 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 (e.g. 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.

These are just a few examples among the many tussles that exist or potentially exist as a result of technological changes and innovations being researched to advance the Future Internet. One challenge for the technologists designing new hardware, software, systems, and platforms, however, is to be aware that technology is not value-free, since it can have several consequences. To some extent, this message has already been taken on board by many policy makers, computer scientists, and systems designers. The recognition that technology-in-use frequently differs from technology-during-design is growing. Thus technology will have socio-economic consequences when released, and the challenge is to take steps to anticipate those consequences where possible, to identify unanticipated emergent consequences as they arise, and to learn the lessons of previous tussle negotiations and resolutions to smooth the implementation of future designs.

5 Conclusions and Future Work

The SESERV Coordination and Support Action was designed to help fill the gap between socio-economic priorities and the Future Internet research community by offering selected services to FP7 projects in Challenge 1. SESERV provides access to socioeconomic experts investigating the relationship between FI technology, society, and the economy through white papers, workshops, FIA sessions, and research consultancy.

In this paper SESERV proposes 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 linked to a number of identified patterns and give examples of such tussles and how these are studied by several European research projects under FP7. The tussle analysis methodology will be evaluated in the context and work of other FP7 projects during the lifetime of the project, and will be enriched and complemented by other techniques; thus forming a toolbox of approaches to understanding the socio-economic issues inherent in FP7 FI projects. This toolbox will be further enhanced and finalized after the workshops, sessions, and consultations, as the project empirically identifies socio-economic issues arising from FP7 and links those to socio-economic tools and methods for analyzing and resolving these issues.

Even though the SESERV project is at its initial phase SESERV can state preliminary observations on whether and the extent to which socio-economic issues are being addressed by the FP7 Future Network project portfolio. At this early stage, SESERV noticed that a significant number of research projects show a major technical viewpoint. For example, MIMAX, EUWB, FUTON, and WIMAGIC try to design technical solutions that achieve efficient spectrum usage for mobile devices. Following the increasing consensus on benefits of incorporating economic incentive mechanisms in technical solutions, several projects like Trilogy, SmoothIT, ETICS, and PURSUIT follow a techno-economic approach. However, SESERV feels that less focus has been given on the interplay of technical, social, and economic objectives. This could be attributed to the difficulty in setting up such a multi-disciplinary team in order to apply a holistic approach, when making technology decisions and/or the inherent difficulty of addressing socioeconomic issues in the Internet when such challenges still exist in the real world.

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