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34 A Competitively Neutral Approach To Network Interconnection

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Executive Summary

This paper develops a consistent, competitively neutral regulatory regime for interconnection between telecommunications networks. It proposes a default bill and keep solution under which carriers split equally those costs that are solely incremental to interconnection, and recover all remaining costs from their own customers. The analysis differs from previous work primarily in that it distinguishes the costs incremental to interconnection from those incremental to increased traffic volume. The paper demonstrates for several basic network types that this default rule is competitively neutral and encourages efficient subscription and interconnection decisions. This default rule resolves serious common cost allocation, externality and gaming problems that arise under current interconnection regimes and under other proposed resolutions.

The key finding is that it is essential to isolate those costs incremental to interconnection *per se*. Local networks are assigned the costs of handling all the possible traffic that their subscribers generate in making or receiving calls. The additional facilities necessary to allow interconnection of two such fully provisioned networks can then be defined as the incremental cost of interconnection. Splitting these latter costs equally between the two networks produces competitively neutral results for basic network types. The paper argues that these results can be generalized to more complex network forms. These results do not depend on the technology used by the networks, on the balance of traffic between them, or on the level of termination costs.

The rapid pace of change of telecommunications market conditions requires a regime that is largely self-administering. As new entrants appear and new types of networks arise, current interconnection regimes become increasingly difficult to administer. This is because they involve intractable problems of allocating substantial common costs among services and among users. The best economists can offer under current approaches is a "second-best" solution that produces significant inefficiencies. This solution also creates opportunities for gaming and regulatory arbitrage that produce more inefficiencies. Furthermore, this solution requires much more information than regulators can acquire, and even the most diligent and clever regulator cannot make necessary adjustments at the pace at which market conditions are changing. The rule proposed here is a largely self-administering scheme that relies primarily on market mechanisms. It also enables efficient outcomes, rather than "second best" solutions attempted under current interconnection regimes.

This proposal resembles other "bill and keep" proposals in that it offers a structural solution to the intractable problems of allocating substantial common costs among services and among users that hamper current interconnection regimes. The FCC has successfully resolved similar problems in recent decades by separating more and less competitive segments of the market. The market for consumer premises equipment (CPE) was separated from that for local service. Enhanced services, particularly computer services, and long distance services were also separated from local service. This structural approach has generally enhanced competition and produced desirable results.

A Competitively Neutral Approach to Network Interconnection

I. INTRODUCTION

1. As both the number and the variety of telecommunications networks continue to multiply, interconnection is becoming increasingly important. As the number of controversies over network interconnection rises, it becomes increasingly useful to reconsider current regulatory approaches. It is not clear that these approaches can accommodate the new types of interconnection that are appearing or keep pace with market developments. We develop below a simple set of principles of interconnection and apply them to current and proposed interconnection regimes.

2. How would we know a good interconnection regime if we saw one? We propose that a good regime should result in a competitively neutral, economically efficient inter-carrier compensation and minimum regulatory intervention. By competitively neutral, we mean that the interconnection regime itself confers no special advantage or disadvantage on any carrier or technology.[1] Whatever advantages or disadvantages existed prior to interconnection remain undistorted by the interconnection regime. For several basic types of networks, we demonstrate below that competitively neutral interconnection is achieved by a simple rule: networks should share equally those costs that are solely incremental to interconnection and bear individually all costs that are not incremental to interconnection. We argue below that this result can also be generalized to more complex networks. We believe this rule is the minimum feasible regulation, and we argue below that it provides a competitively neutral and, with respect to interconnection, efficient outcome.

3. Our approach to the problem of interconnection differs from the usual treatment in the economics literature. The most fundamental difference is that the interconnection literature typically accepts existing institutional arrangements as given, then attempts to find pricing rules to navigate the morass of problems that arise from these arrangements.[2] In contrast, regarding institutional arrangements we begin *tabula rasa*, with a blank whiteboard, and consider whether alternative arrangements might lead to a simple, competitively neutral, efficient result.[3, 4]

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[1] This corresponds to the definition of competitive neutrality adopted by the FCC for Universal Service purposes. See *In the Matter of Federal-State Joint Board on Universal Service*, CC Docket No. 96-45, 12 FCC Rec'd 8801, ¶47.

[2] A recent state of the art presentation of this approach is found in Jean-Jacques Laffont and Jean Tirole, *Competition in Telecommunications*, MIT Press, 2000. An earlier example is Robert D. Willig, "The Theory of Network Access Pricing" in *Issues in Public Utility Regulation*, H. Trebing, editor, Michigan State University Press, East Lansing, 1979.

[3] This is not our only departure from the customary approach. Very briefly, our main focus is on cost, rather than demand, and we distinguish costs incremental to interconnection from those incremental to traffic. We also depart from the typical view of the "network externality" problem, as discussed below. We develop these points more fully below.

4. Our differing approach is largely motivated by the rapidity with which new forms of interconnection are developing and market conditions are changing. This contrasts to the necessarily glacial pace at which even a supremely competent regulator can regulate in a society that values due process, eschews arbitrary and capricious exercise of power, and in which regulators have limited specific knowledge of market conditions.[5] From this perspective, reexamining the institutional arrangements seems the only workable approach to untangling the current inconsistent assortment of interconnection rules that have been crafted over recent decades for various telecommunications sectors to meet various policy objectives.[6] Despite this somewhat radical approach, we believe our analysis is generally consistent with previous analyses, in the sense that differences in results stem primarily from differences in assumed institutional arrangements. We also find that solutions similar to those we propose have been suggested previously by others, but were not adopted for reasons that apparently no longer apply.[7] We discuss briefly below, mainly in footnotes, how our analysis relates to the previous literature.

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[4] Our willingness to consider alternative institutional arrangements is uncommon, but not unique. For other recent examples, see Gerald W. Brock, "The Economics of Interconnection," Teleport Communications Group (1995). The three component articles in this publication were placed in the record in CC Docket No. 95-185 as attachments to comments by Comcast Corporation, Teleport Communications Group and Cox Communications. See also, Patrick Degraba, "Bill and Keep at the Central Office As the Efficient Interconnection Regime," Office of Plans and Policy, Federal Communications Commission, OPP Working Paper No. 33 (December 2000).

[5] See Friedrich A. Hayek, "The Use of Knowledge in Society," *American Economic Review*, XXXV, No. 4; September, 1945, 519-30, reprinted at http://www.virtualschool.edu/mon/Economics/HayekUseOfKnowledge.html.

[6] Recent history has demonstrated that in the current climate firms have difficulty predicting accurately what institutional rules will be in their interest in even the relatively short term. For example, reciprocal compensation arrangements that incumbent LECs believed were favorable to their interests have proved extremely costly. Over a span of three or four years, incumbent LECs claim that rapid growth in dial up Internet access traffic raised their payments to competitive LECs from small amounts to over $2 billion [Letter of W. Scott Randolph, Verizon Communications, to Magalie R. Salas, Secretary, FCC, November 1, 2000 in CC Docket No. 99-68]. This development took incumbent LECs utterly by surprise. At present, there is widespread uncertainty about such unknowns as the future impact of Internet telephony, broadband markets, changes in reciprocal compensation rules, various court rulings, and many other factors. This uncertainty seems greater than in the past, making it more difficult for firms to be sure what specific rules might later turn out to have been in their interest. This may make a general reexamination of basic institutional arrangements more feasible than usual, because no party can quite be sure what rule it would prefer in tomorrow's market. These conditions invite something of a "Rawlsian constitutional convention" [John Rawls, *A Theory of Justice*, The Belknap Press of Harvard University Press, 1971] in which parties seek a "fair game" because they do not know what their future interests will be.

[7] For the history and background of the development of current institutional arrangements, see Gerald W. Brock, *Telecommunication Policy For the Information Age: From Monopoly to Competition,* Harvard University Press, 1994.

II. EFFICIENT INTER-CARRIER COMPENSATION AS THE FOCUS FOR INTERCONNECTION POLICY

5. We believe it has become useful to depart from tradition by focusing on inter-carrier compensation rather than on end user charges. Until fairly recently, the primary focus of interconnection policy has been the distribution of costs among end users, and the literature has focused on end user pricing. More recently, interconnection policy has also been seen as a means of promoting competition.[8] Today, however, the public switched network has become a network of networks. As a result, interconnection's importance is no longer simply as a mechanism for transferring subsidies from certain carriers (or end users) to others. If the national economy is to continue to grow and prosper, it is increasingly important that interconnection be economically efficient. We therefore propose to redirect the focus of interconnection policy to inter-carrier compensation.

6. In the past, legislatures and regulators have shaped interconnection regimes to further a variety of policy goals. Universal service, the cross-subsidization of high cost users by low cost users,[9] was typically the driving policy consideration.[10] With the Telecommunications Act of 1996, Congress fundamentally altered this landscape. Regulated monopolies were to be supplanted by competitive markets, and cross-subsidization was to be replaced by explicit, "specific, predictable, and sufficient … mechanisms to preserve and advance universal service."[11] Universal service considerations are no longer to dominate interconnection policy.

7. We assert that competitive neutrality and inter-carrier economic efficiency should now become the primary interconnection policy consideration. There exists an economically efficient, competitively neutral solution if the problem is formulated in terms of inter-carrier

[8] Interconnection can be viewed as the means by which nascent competitive networks obtain vital inputs from dominant, incumbent networks. *See generally In re* Implementation of the Local Competition Provisions of the Telecommunications Act of 1996, CC Docket No. 96-98, *Report and Order*, 11 FCC Rcd. 15,499, 16,012-13 (1996) (Local Competition Order), *rev'd in part on other grounds*, Iowa Utilities Board v. FCC, 120 F.3d 753 (8th Cir. 1997), *rev'd*, AT&T v. Iowa Utilities Board, 119 S. Ct. 721, 733, 738 (1999).

[9] The economics literature generally does not address this type of cross-subsidization. It focuses, rather, on "Ramsey pricing," which seeks to minimize the inefficiency caused by recovering common costs through prices above marginal cost. The Ramsey solution raises prices most on those customers who have low demand elasticity. For a typical application, see Laffont and Tirole, fn 2 *supra.*

[10] Much of the economics literature of interconnection expresses this universal service policy as correcting a network externality. That is, all users benefit when another user is added to the network, because they all have access to the new user. The potential new user, however, compares the price she is required to pay only to her private benefits, ignoring the "external" benefits to other users. This is the theoretical basis for advocating a subsidy that lowers the price in order to correct for the externality. For typical treatments, see Robert D. Willig, , fn 2 *supra*, and Laffont and Tirole, fn 2 *supra*.

[11] Codified at 47 USC 254(b)(5).

compensation.[12] The economic efficiency of inter-carrier compensation affects both the structure of the industry and, more importantly, the contribution the telecommunications sector makes to the nation's economic growth and productivity. Because inefficiency in this increasingly important sector can substantially degrade overall national output, interconnection policy should now focus on inter-carrier efficiency.

8. An alternative way of stating this last point is that competitive neutrality has become increasingly important in interconnection. Current interconnection rules have distorted production and output in telecommunications. Rates that diverge greatly from true economic costs, and rate *structures* that diverge from true cost structures, have resulted in inefficient production and behavior that is rational only because of artificial rules.[13] The industry has reshaped itself extensively to respond to artificial incentives that are often an unintended consequence of artificial rules.[14] This often diverts traffic from the public switched telephone network onto such alternatives as private lines, competitive access providers, and, perhaps next, Internet telephony. Regulators and parties have expended much energy in erecting artificial boundaries to maintain artificial distinctions and artificial prices. The market relentlessly undermines these regulatory walls,[15] particularly when inconsistent rules encourage parties to adopt avoidance strategies.[16] The regulatory walls eventually crumble, but in the meantime efficiency suffers. We may have reached the point at which telecommunications has become so important that our society can no longer afford such inefficient policies. It may be time for a competitively neutral interconnection rule that does not distort choices among technologies or among firms.

9. Focusing on inter-carrier compensation enables us to avoid two serious stumbling

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12 As a bonus, this solution eliminates the danger of a dominant LEC extending its market power to monopolize interconnected markets. This is a major concern in the literature, and a very difficult problem under the access charge interconnection regime. See, e.g., Gerald W. Brock, "Interconnection and Mutual Compensation with Partial Competition," in Brock (1995), fn 4 *supra*; Laffont and Tirole, fn 2 *supra,* especially chapter 5.

13 For illustrations see the background and discussion sections of *Access Charge Reform First Report & Order*, FCC 97-158.

14 Perhaps the most vivid current example is the phenomenal growth of CLECs specializing in terminating ISP-bound traffic. See comments submitted in *In the Matter of Inter-Carrier Compensation for ISP-Bound Traffic*, CC Docket No. 99-68 and CC Docket No. 96-68.

15 Robert Frost may have dabbled in economics on the side. See *Mending Walls*, reprinted at http://www.english.upenn.edu/~afilreis/88/frost-mending.html

16 This process used to be called "bypass," meaning that a customer avoids paying an above-cost subsidy by finding an alternative means of interconnecting. The currently more fashionable term is "arbitrage," which encompasses more broadly numerous methods of exploiting differences in regulation among alternative services. A current example is the concern of many that advances in "Internet telephony" will encourage callers to avoid the entire "access" regime.

blocks. The first is that the traditional end user focus requires viewing inter-carrier calls (local or long distance) as services among many others that carriers market to end users. This makes most network costs, particularly loop costs, common costs to be allocated among these various services. Only markets can make such an allocation correctly. Regulators cannot possess the requisite specific knowledge.[17] The problem is intensified severely by the institutional rule that the calling party's network pays the entire cost of the call. Because this cost includes an allocation of common costs, the calling party's network ends up paying a share of the common costs of the called party's network. There is no perfect solution to these cost allocation problems, largely because regulators cannot know how benefits are distributed between the parties. That is, regulators cannot see individuals' demand functions. Any allocation a regulator can make is arbitrary (in the economic sense), yet even a small allocation error can produce massive distortions.[18]

10. The second stumbling block we avoid is that, under current institutional arrangements, end users have no direct control over access arrangements. Under the access charge regime, interexchange carriers (IXCs) must purchase access from local exchange carriers (LECs) on both the originating and terminating end of calls. By law and FCC interpretation,[19] IXCs must average the access charges they pay across all LECs, so that IXC customers pay the same rate whether they call to (or from) a high cost or a low cost LEC. IXCs are not permitted to pass through the access charges incurred on a particular call to the end user who makes that call.[20] Thus, even if an omniscient regulator existed who could discern the correct (i.e., socially efficient, incorporating all externality effects) inter-carrier cost allocations, these would not necessarily result in correct end user rates. The parties to a call are not empowered, under current arrangements, to choose the lowest cost means of completing a call of the quality and other characteristics they prefer. Therefore even correct inter-carrier cost assignments cannot assure efficient outcomes under current arrangements.

11. By focusing on inter-carrier compensation, we avoid these two inter-related problems entirely. We will show that the efficient allocation of interconnection costs between carriers is independent of how the calling and called parties bear the cost of a call. Nor does the balance of traffic between networks affect the efficient allocation of interconnection costs. It does

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[17] Even if they could gather the data, it would be out of date before they could assemble it. The genius of markets is their ability to make rapid, decentralized decisions that are efficient. See Hayek, fn 5 *supra*.

[18] The recent rapid growth in ISP minutes subject to reciprocal compensation agreements between incumbent LECs and competitive LECs is a compelling illustration of the result of a "small" error in setting compensation rates and structure.

[19] See 47 USC 254(g) and *Implementation of Section 254(g) of the Communications Act of 1934, as amended*, CC Docket No. 96-61 (FCC 96-331).

[20] In effect, such policies give every LEC a monopoly over access to and from its end users. *See LEC Pricing Flexibility Order and NPRM*, 14 FCC Rcd at 14316-17, para. 186.

not matter which network's subscriber caused a call by initiating it.[21] The carriers' retail rate structures, the ways they recover their costs from their end users, are not our focus.[22] We are concerned here with inter-carrier compensation rather than end user charges.

12. Brock (1995) makes the important point that the FCC's 1980 *Computer II* decision to deregulate customer premises equipment (CPE) was equivalent to mandating interconnection with customer-owned CPE and setting a zero interconnection rate for CPE. That is, local carriers could no longer charge for or control end users' purchase or use of CPE that met FCC technical standards. Prior to 1980, CPE had been a profitable venue for LEC price discrimination. LECs priced CPE usage as many discrete services. LECs could, and did, charge usage fees for every jack and every piece of equipment the customer wished to attach. The resulting common cost allocation problems were insoluble and pricing was based primarily on marketing estimates of demand elasticities for particular services.[23] The *Computer II* decision gave customers complete control of (and responsibility for) the wiring and equipment on their side of the network interface device (NID). In a somewhat analogous manner, we are suggesting that, just as CPE was separated from local service, inter-network interconnection can also be separated from local service in a manner that empowers end users.

13. It is difficult to overestimate the impact of *Computer II*'s decision to give customers the right to purchase CPE outright, rather than only to buy discrete CPE services from the LEC. We will not attempt to prove this assertion here, but we believe that the recent development of the Internet, and of much of Information Technology, would not have happened if CPE (for example, modems) were still marketed only by LECs. The blossoming of the CPE market into a highly competitive industry offering a wide variety of choice at low cost and rapid technological advances, and enabling previously unknown possibilities such as the increasingly numerous Internet services, is arguably a direct consequence of the deregulation of CPE.

14. We are suggesting that, in a manner similar to CPE, interconnection can be separated from local network services. At present, LECs retain access rights to their customers lines. They sell discrete access services to IXCs and other interconnecting carriers, who in turn sell individual calls to individuals. Instead of this arrangement, subscribers could directly purchase unlimited access to their own lines. Although this paper does not address the manner in which carriers retail their services, we do not exclude any particular arrangements. Our point is

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[21] In fact, the entire concept of the "directionality" of a call is rapidly becoming highly ambiguous, if not entirely meaningless. In international telephony, for example, the prevalence of arrangements such as "call-back plans" make it very difficult to identify "true" causation. Similarly, what is the direction of causation when a person returns a call in response to an answering machine message (or an E-mail)? This point is discussed in Degraba, fn 4 *supra*. For an Internet-related analysis, see Michael Kende, "The Digital Handshake: Connecting Internet Backbones," FCC Office of Plans and Policy Working Paper No. 32, September, 2000, p. 36ff. http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp32.pdf.

[22] We do address below an end user pricing problem related to interconnection with a dominant LEC.

[23] This is discussed in considerably greater detail in Brock (1994), fn 7 *supra*, Chapter Six.

that the best way to achieve efficiency may be first to "get inter-carrier compensation right,"[24] then to address the end user market separately.

15. Getting inter-carrier compensation right does not guarantee that end user charges will also be right, but it is a major step in that direction. Interconnection policy alone cannot cure underlying problems, such as possible dominance in local exchange markets,[25] but it can limit the harm generated by such dominance and thus contribute toward achieving solutions. Efficient interconnection policy can prevent a dominant carrier from using its control over interconnection to extend its market power to other markets, to leverage its market power to extract monopoly rents from interconnectors, or to erect artificial barriers to competitive entry.[26] That is, interconnection policy can restrict a dominant LEC to exploiting only its own customers. If a dominant carrier does try to exploit its own customers, the chances that a competitor can contest the market are improved. Regulators may wish to influence a dominant carrier's end user charges, but interconnection policy is not the correct tool for this purpose. By focusing exclusively on inter-carrier compensation here, we assert that the first step in getting end user charges right is to achieve efficient inter-carrier compensation, and that this is the proper focus of interconnection policy.

III. TWO CRITERIA FOR INTERCONNECTION REGIMES

16. As long as there are dominant local networks, it may be necessary to mandate and regulate interconnection. A dominant network may be able to disadvantage a competitor by either of two basic strategies. It may simply refuse interconnection and thereby force subscribers of other networks to subscribe to it in order to connect to its subscribers.[27] Or it may impose (discriminatory) charges on calls to or from subscribers of other networks, thereby inducing these customers to join its network or taxing, in the economic sense, the other networks.[28] Neither of these strategies could be effective, and no network would have an incentive to refuse interconnection,[29] if no single network held a commanding market share, but they become

[24] The term "right," as used in this paper, should be understood as shorthand for socially efficient, that is, economically efficient taking into account any external costs or benefits.

[25] Other analysts have also noted this problem. "The twin objecives of allocative and productive efficiency cannot both be attained by the single instrument of the access price, so the aim is to achieve the optimal tradeoff." Mark Armstrong and John Vickers, "The Access Pricing Problem with Deregulation: a Note," *The Journal of Industrial Economics*, XLVI, March 1998, p. 116.

[26] Gerald W. Brock, "Price Structure Issues in Interconnection Fees," in Brock (1995), fn 4 *supra*.

[27] Brock (1994), fn 7 *supra*, discusses how AT&T successfully used this strategy in the early 1900s to build a monopoly.

[28] See Brock (1995), fn 4 *supra*, for an extensive discussion of these problems, particularly in an access charge regime.

[29] Kende (2000), fn 21 *supra*, discusses these incentives in the context of a competitive market, i.e. the Internet.

increasingly attractive as the largest network approaches market dominance. In the presence of a dominant carrier, a regulatory remedy may be necessary.

17. If a regulatory remedy is necessary, it should minimize the extent of regulatory intervention. Absent regulation, a dominant network may be able to impose crippling disadvantages on potential competitors. The result may be exploitation of customers and potential competitors as well as inefficiencies that inflict significant net losses on society. But will a regulatory remedy do more good than harm? The problem is that regulation itself can also impose significant costs.[30] This is particularly problematic when regulators "get it wrong," an outcome which is hardly unprecedented and the more likely the more information is required to "get it right." An ideal solution, therefore, should minimize the information regulators need.

18. So we propose two criteria by which to judge potential mandatory interconnection regimes. Do they result in economically efficient inter-carrier compensation? And are regulators likely to get it right? The first criterion means that the correct pricing signals are sent to networks making investment and make/buy decisions, and thus potentially also to consumers making subscription decisions.[31] The second criterion means that regulators do not need many facts or much data to administer the regime. Ideally, regulators could limit themselves to stating fairly simple principles or rules and allow the parties to negotiate efficient solutions suited to their particular circumstances. In such a regime, disputes would be resolved primarily through ordinary commercial procedures such as negotiation and arbitration.[32] We propose that an interconnection regime that meets these two criteria, efficiency and simplicity, would permit an efficient and competitive telecommunications system to develop and enable it to adapt rapidly and smoothly to changing technologies and market conditions.

19. In proposing these two criteria, we should note that our goal is relatively modest.

[30] Among these are litigation expense, delay, uncertainty, opportunities for "rent-seeking" behavior by interested parties, and the real possibility of error, even assuming regulators are both highly intelligent and benevolent.

[31] Competition forces carriers to price according to their costs and cost structure. See Gerald W. Brock, "Price Structure Issues in Interconnection Fees," in Brock (1995), fn 4 *supra*, illustrates. If a carrier is market dominant, of course, it may not pass correct pricing signals to its customers. As discussed above, interconnection policy alone cannot cure underlying market structure problems such as dominance, but it can be an important step toward resolving such problems. An inefficient interconnection policy, in contrast, virtually guarantees that customers will face incorrect pricing.

[32] The Coase Theorem states that parties will negotiate efficient solutions to rights allocation problems, so long as the rules are clearly stated and transactions costs are low. Coase's Theorem was foreshadowed in Ronald H. Coase, "The Federal Communications Commission," *Journal of Law and Economics*, v.2 (1959), pp. 1-40, and then made explicit in his "The Problem of Social Cost ," *Journal of Law and Economics* v. 3, no. 1 (1960), pp. 1-44. Coase won the Nobel Prize in Economics in 1991 "for his discovery and clarification of the significance of transaction costs and property rights for the institutional structure and functioning of the economy." [Press release of The Royal Swedish Academy of Sciences, October 15, 1991, at http://www.nobel.se/economics/laureates/1991/press.html .]

We do not seek an interconnection regime that will resolve all the problems of telecommunications. It would be a significant improvement to discover one that, unlike the current regimes, does not add new or compound old problems. We do assert, however, that inter-carrier and retail rate structures can be addressed separately, just as CPE problems were resolved by treating CPE separately. In fact, we believe these problems can be solved only if inter-carrier and retail issues are addressed separately.

IV. EFFICIENT INTERCONNECTION RULES IN A SIMPLIFIED NETWORK

20. Real world networks are by nature so complex that it is very difficult to analyze them. Economists have always developed their principles by abstracting from real world complexities to capture essential features, and we resort to that technique here. We begin with a simplified, highly abstract representation of a network to demonstrate the principles of economically efficient interconnection. In the text, we attempt to develop these principles through simple, graphical illustrations employing a stylized linear network. Footnotes present a more general mathematical derivation. In a later section, we derive the same principles mathematically for each of two other fundamental types of networks.[33] Although we do not attempt to prove these results for the completely general case, real networks can be represented reasonably well as a composite of these three fundamental building blocks. We therefore believe the principles apply to the more complex forms.

21. We make a number of simplifying assumptions in order to clarify the exposition. Later we will discuss the extent to which we can generalize these insights when some of these assumptions are relaxed. For now, our networks ignore scale economies, trunking efficiencies, and the many other engineering considerations that shape any real network. We thus abstract from the particular technology used to solve the problem of connecting any group of customers. We focus instead on the fundamental, underlying facilities requirements faced by each network in serving its subscribers. We assume that each network has access to the same technology set and employs brilliant engineers who select the most cost-effective means of provisioning the underlying facilities requirements. But we are not concerned with how the engineers work their magic, only with the abstract, underlying facilities requirements.

A. A simplified measure of facilities: *urlinks*

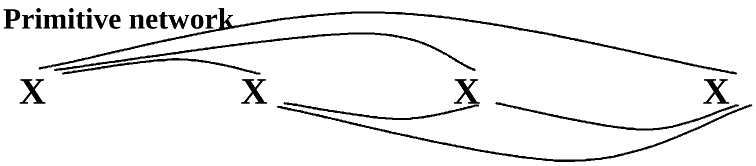
22. Let us begin by imagining a small network with four identical subscribers. We want to determine what facilities are necessary to meet the following two requirements: First, any two subscribers to the network should be able to connect with each other. Second, there should be no call blocking. This means that any subscriber can always complete a call to any other subscriber who is not already engaged in a conversation. The call will not be blocked by

[33] In addition to the linear network, we examine a mesh network and a fiber optic ring connecting central offices of any configuration.

inadequate facilities.[34] Put differently, the network has sufficient facilities to enable all possible simultaneous conversations to take place.

23. The most primitive network imaginable would meet our two requirements simply by using a separate line to connect each pair of subscribers. With four subscribers, each depicted by an X, we would need six lines, as shown in Figure 1. Note that this network consists entirely of lines and has no switching capability at all. For five subscribers, we would need ten lines, for six we would need 15. In general, for n subscribers, this type of network requires $(n^2-n)/2$ lines.

Figure 1: Primitive network



24. We use this facilities requirement for this primitive network as an abstract measure of required facilities. Engineers, of course, do not construct real networks by stringing a line between each pair of subscribers. As soon as n gets very large, the number of links required becomes astronomical (and subscribers would find it annoying to have n-1 separate lines).[35] Engineers, therefore, use various technological devices to reduce costs.[36] One basic method is to substitute switching capabilities for some of the links. Switches, multiplexers, and other line concentration devices may provide these substitutes for links. We are not concerned with precisely how the engineers provision the network. Regardless of the particular combination of links and switching actually used, we can think of the basic facilities requirement as a combination of links and switching that is equivalent to $(n^2-n)/2$ links for a network of n subscribers. We coin the term ***urlink*** to indicate the facilities required to enable one direct connection between one pair of subscribers,[37] noting that urlinks may be supplied by various

[34] We relax this "non-blocking" assumption later. We will also relax the assumption that the "subscribers" represent individuals rather than, say, central offices.

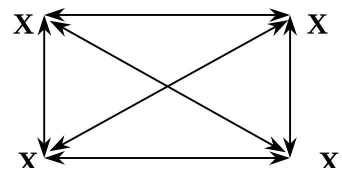
[35] The very earliest telephone service seems to have taken this form, with subscribers renting telephones and providing their own lines directly to those individuals they wanted to call. The first switching (exchange) services began in 1878, after the number of subscribers had grown to the point that direct connections were no longer efficient. See Brock (1994), fn 7 *supra*, p. 63.

[36] These devices also improve reliability and enable other features such as advanced intelligent network services, for example Call Waiting or Caller ID, but we want to focus on basic interconnection in order to keep this simple. These other features have little or nothing to do with interconnection, because they are provided primarily within a single network.

[37] The word urlink is much shorter than "underlying link" or "link equivalent,"which is its meaning. The prefix *ur-* in the Germanic languages suggests the concepts of original, underlying, or primitive. The term *urlink* also sounds like the engineering term *erlang*, a measure of the circuit capacity required to meet expected demand. The concept of an urlink is similar, but not quite identical, to an erlang.

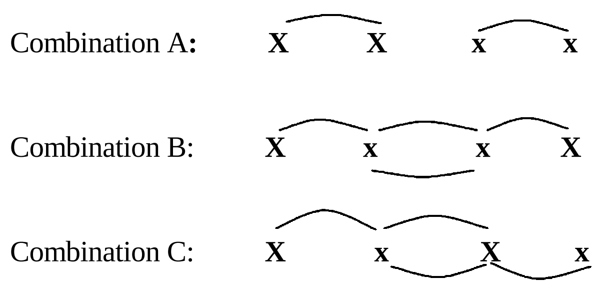
combinations of links and switching. Thus, we can say a network of four subscribers has an underlying facilities requirement of six urlinks. A network of five subscribers requires ten urlinks, and a network of n subscribers requires $(n^2-n)/2$ urlinks.The mesh network is a basic network form similar to our primitive network, in that it uses the same number of lines; but it adds a switch at each node. The mesh network provides added reliability because there are multiple paths between each pair of subscribers. If one link fails, a call can be routed over alternative links. The mesh also requires $(n^2-n)/2$ links. We extend our interconnection principles to mesh networks later, but base our initial discussion on the even simpler linear network form, because a mesh becomes very difficult to depict graphically as n increases.

Figure 2: Mesh network



25. For our graphical depictions in the text, we use a linear network. To determine the facilities required, we write down all the possible simultaneous two-party conversations. We use a long dash to represent a unit of transport *and related facilities* that we will again call an urlink.[38] Using upper and lower case to distinguish between calls, there are three possibilities for two simultaneous 2-party conversations, as shown in Figure 3.

Figure 3: Possible conversations among 4 parties



26. In words, Combination A needs only two urlinks since there is only a left side and right side conversation. The remaining possible combinations need these plus two in the center, since both the conversations cross the center of the network. In Combination B, the center parties (x-x) require one urlink and the outside parties (X–X) require three. In Combination C, each conversation requires two urlinks. We can denote the facilities needed for our four-party network to meet our two requirements as in Figure 4.

Figure 4: Facilities required for a 4-party network

X — X ═ X — X

27. In words, a network of four parties (subscribers) can have a maximum of 2 simultaneous two-party conversations (the number of dashes in the center) and requires 4 urlinks (the sum of all the

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[38] We use this term here as shorthand to represent the facilities (link and switching) needed to route one conversation between two adjacent subscribers. The astute reader will soon note that for linear networks we are using a slightly different definition of urlink that now includes some switching capabilities, enough to route calls. We think it less confusing to recycle the term than to invent another, and we use the term only for counting basic facilities requirements, not for comparisons between different network topographies.

dashes) to allow every possible two-party conversation to take place.

28. This diagram is a deliberate abstraction that does not specify the network architecture or technology that is used to meet the requirements that any two parties can connect and that there is no call blocking. In the real world, a network could meet these requirements with a ring, star, mesh or any other imaginable architecture; wireline or wireless links; and circuit or packet transmission. We are also abstracting from cost-saving techniques that real networks use to economize on links.[39] We ignore possible scale economies or trunking efficiencies and assume initially that the network is engineered for zero call blocking. Finally, this simple network does not have any redundant links to improve reliability.[40] In other words, we are focusing on the raw capacity required and abstracting from engineering techniques used to provision this raw capacity (urlinks) economically.

29. We can generalize this depiction to any number of parties. For a linear network of n subscribers, the maximum number of simultaneous two-party conversations is n/2. (Logically, each party can engage in only one conversation at a time.) To ensure that any combination of n/2 conversations can occur simultaneously[41] requires $(n/2)^2$ links.[42]

B. Adding subscribers in a linear network

30. We are now almost ready to explore interconnection between two networks; but first we need to consider what happens as additional parties subscribe. We make two more initial assumptions to simplify the analysis. Later we relax these. We assume all parties are identical (and choose their initial network randomly). We also assume for now that each urlink has the same cost.

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[39] One such technique is engineering to accept more than zero call blocking. We address this possibility below, but for now maintain the zero blocking assumption.

[40] Mesh and ring networks, of course, have built-in redundancy for improved reliability.

[41] That is, a call attempt might fail because the called party's line is already busy, but not because of circuit blockage.

[42] A mathematical proof is fairly simple. In the "worst case," which requires the most links, the parties in the center of the network call each other, then the next nearest pair, continuing until the pair at the extreme ends of the network call each other. The "center" call requires one link, the next requires three, and the *i*th call requires (2*i*-1) links. For a network of n subscribers, in which the maximum number of possible calls is n/2, the "extreme" call requires 2(n/2) –1 = n-1 links. The sum of all the required links is

$$\sum_{i=1}^{n/2}(2i-1) = 2\sum_{i=1}^{n/2} i - \frac{n}{2} = 2\left[\frac{\left(\frac{n}{2}\right)^2 + \left(\frac{n}{2}\right)}{2}\right] - \frac{n}{2} = \left(\frac{n}{2}\right)^2.$$

31. If two more parties subscribe to the X network, then a six-party network in our notation would be diagrammed as in Figure 5. Three simultaneous calls are possible, so three urlinks are needed across the center of the network. This network meets our two requirements, that any two parties can connect and that there is no call blocking.

Figure 5: Six party network

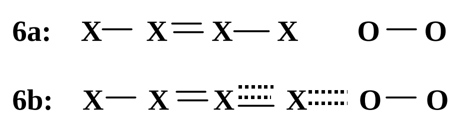
X— X═X≡X═ X— X

32. Notice that the original four-party network had an average of one link per party, but adding the two new parties requires five more links. The parties benefit equally from the network (in the sense that each can call any of the others), so instead of making the new parties pay for all the additional links, every subscriber pays a proportionate share of the additional links.[43] The average number of links per party rises from 4/4 = 1 per subscriber to 9/6 = 1.5 per subscriber. As more subscribers are added, the benefits of the network increase, but the number of links needed per subscriber also rises.[44] The network will add new parties until there are no more potential subscribers or the price (average cost) rises to the point at which some subscribers begin dropping off the network.

C. Assigning the incremental cost of interconnection

33. What is the incremental cost of interconnection? Suppose the two parties who joined Network X in Figure 5 had instead already subscribed to another network, Network O? Comparing Figures 6a and 6b, we see that to meet our two requirements, interconnection requires four additional links (dotted in Figure 6b).[45] This is the incremental cost of interconnection.

Figure 6: Interconnection of a 4-party network with 2-party network



34. It is worth noting that the interconnected network of Figure 6b has precisely the same facilities requirements as the six party network of Figure 5. In this case, interconnection is

[43] The network is unable to discriminate among subscribers, because any subscriber could drop from or join the network. Thus each is potentially a "marginal" subscriber.

[44] More generally, because the number of links is $(n/2)^2 = n^2/4$, the average number of links per subscriber is always $n^2/4/n = n/4$. As the number of subscribers increases, each subscriber benefits from being able to call more people, but the "raw" capacity needed per subscriber rises. We are abstracting from the engineering techniques that can offset this diseconomy of scale in real networks.

[45] More generally, if a linear network with a subscribers interconnects with a linear network of b subscribers, the number of incremental links required is $ab/2$. Recall that the total links needed to meet our two requirements (enabling all possible connections and the maximum possible number of simultaneous conversations) is $n^2/4$. If the size of the interconnected network is $n = a + b$, the total links requirement is $(a + b)^2/4 = (a^2 + 2ab + b^2)/4$. Before interconnection, the two separate networks needed $a^2/4$ and $b^2/4$ respectively. Thus the number of incremental links required for interconnection is the difference, $2ab/4$ or $ab/2$.

precisely equivalent to subscription. Ideally, our rule for allocating responsibility for the incremental interconnection links should not give parties an incentive to masquerade as networks[46] or as subscribers, or to rearrange calling patterns,[47] in order to exploit the rules. That is, an ideal rule will not distort decisions.

35. How should responsibility for these four incremental links be assigned? Suppose each network were assigned a share proportional to its number of subscribers. The X network would pay for two-thirds of the four incremental links (2.67 links), and would have a new average of (6.67)/4= 1.67 links per subscriber. The O network would be responsible for 1.33 additional links, raising its average to 2.33/2 = 1.17 links per subscriber. However, a subscriber to either network receives precisely the same benefits: non-blocking access to the same subscriber list. Therefore, subscribers to the X network would be better off if they switched to the O network. As the O network grew, its links per subscriber would increase (and losing subscribers would reduce links per subscriber on the X network). The artificial price wedge created by this interconnection cost assignment would only disappear when the networks became equal in size. Eventually, subscribers would migrate until each network would have 1.5 links per subscriber.

36. The discussion in the previous paragraph suggests a surprising result, that dissimilar-sized networks must share equally the incremental cost of the facilities required to interconnect them. Under this "Split the Incremental Cost of Interconnection" rule, the O network, with only two subscribers, must pay for the same number of incremental links as the X network, even though X has twice as many subscribers. This means, of course, that the cost *increase* faced by O subscribers is greater (from 0.5 to 1.5 links per customer) than that faced by X subscribers (from 1.0 to 1.5 links per customer). This seems reasonable, because the O customers are gaining access to four additional parties, while the X subscribers are gaining access to only two more parties.[48] Following this rule yields the same number of links per subscriber for each network.[49] That is, the raw capacity burden per subscriber is the same on

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[46] A difficult problem in access regimes, and even in some forms of bill and keep proposals, is that, when traffic is primarily "inbound," an end user may have an incentive to claim it is a network in order to avoid bearing transport costs. If traffic is primarily "outbound," a network may wish to claim it is an end user for the same purpose. See Degraba, fn 4 *supra*.

[47] Networks or users can often arrange their traffic flow to make it appear mainly inbound when doing so is advantageous. See fn 21 above.

[48] A bit of simple algebra shows that, for linear networks, the average cost increase for subscribers to one interconnecting network is always equal to ¼ link per subscriber on the other network. Splitting the incremental cost of interconnection equally, each network would be responsible for an additional $ab/4$ links (half the total increment of $ab/2$). For network X, the average cost rises by $ab/4a = b/4$. Similarly, the average cost on O rises by $ab/4b = a/4$ links per subscriber.

[49] This result also generalizes to interconnection between two linear networks of any size. Recall from the previous footnote that the number of incremental links necessitated by interconnection of a network of a subscribers with a network of b subscribers is $ab/2$. If this increment is assigned equally to the two

each network. Since full, non-blocking interconnection allows subscribers to either network precisely the same benefits, failure to balance links per subscriber does not produce a stable outcome. The burdened network will lose subscribers and the favored network will gain subscribers until the burden is equalized.

37. When we compare Figures 6a and 6b we can see that interconnection does not increase the maximum number of simultaneous calls (the number of links in the center of the combined networks). Prior to interconnection, three simultaneous calls are possible: two on the (four party) X network and one on the (two party) O network. The interconnected six-party XO network also accommodates three simultaneous calls. Thus interconnection only increases the number of parties it is possible to call, not the number of simultaneous calls. This point will prove significant later, when we drop the assumption of no call blocking.

38. Note that we have achieved this efficient allocation of costs between networks without any reference to how the calling and called parties bear the cost of a call, to which network caused a call by initiating it, or to the balance of traffic between networks. We thus avoid the intractable common cost allocation problems encountered in the traditional approach.

D. Networks should recover from their own subscribers all costs not incremental to interconnection: the "BASICS" rule

39. Our analysis suggests a second principle, that *only* the costs incremental to interconnection should be split. Therefore, all remaining network costs should be recovered from the network's own subscribers. In our example in Figure 6b, dividing the total links (9) equally between the networks would give the X network 4.5/4 = 1.125 links per subscriber. In contrast, the O network would have 4.5/2 = 2.25 links per subscriber.[50] Even if the networks were the same size, but dissimilar in cost, including the internal network costs would create an artificial cost difference. We consider this point more fully and distinguish more clearly between internal network costs and interconnection costs in the next section.

40. We can now combine our two principles to form a rule we will name "Bill Access to Subscribers, (Incremental) Interconnection Costs Split," or "**BASICS**." The second half of this acronym is the rule, developed in the previous section, that the costs incremental to

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networks, their respective *total* numbers of links will be $a^2/4 + ab/4$ and $b^2/4 + ab/4$. To obtain their average links per subscriber, we divide each network's total capacity by its number of subscribers. We obtain, respectively, $(a^2 + ab)/4a$ and $(b^2 + ab)/4b$. Each of these expressions reduces to $(a + b)/4$. Thus if the incremental links are split equally, each network ends up with the same average number of links per subscriber, regardless of their respective sizes. No other allocation of incremental links will produce this equality. This equality of links per subscriber also results if this rule is applied to mesh networks or to fiber optic rings (see Section [VI] below).

[50] More generally, because the previous footnote demonstrated that splitting incremental links equally produces equal average burdens regardless of the sizes of the separate networks, adding any additional costs would produce an unstable outcome.

interconnection should be split equally between the two interconnecting networks. The first half refers to the requirement that each network collect all remaining costs (those not incremental to interconnection) from its own subscribers. In particular, access rights to subscribers' lines are not sold to interconnecting networks on a per minute basis, as under current access rules. Instead, all access rights are sold directly to the subscribers themselves. We confess that our name for this rule is somewhat awkward, and freely admit that the name was crafted primarily for the sake of its acronym.

E. Interconnection among more than two networks

41. In the case of more than two networks, the BASICS rule would apply *seriatim*. That is, the initial interconnection forms an interconnected network. As additional networks join, each would do so on a BASICS basis. In each case, the network joining would bear half the incremental costs of the new interconnection. The networks previously interconnected would bear the remaining incremental costs, which would be distributed among these networks on a per subscriber basis. This allocation would produce the same results as above, and the result would be the same (an equal urlinks per subscriber burden) regardless of the order in which networks joined.

V. DISTINGUISHING COSTS INCREMENTAL TO INTERCONNECTION FROM INTRA-NETWORK COSTS: INTERCONNECTION OF LESS THAN FULLY PROVISIONED NETWORKS

42. If the BASICS Rule is to be implemented, it is essential to identify those costs that are incremental to interconnection *per se*. It is particularly important to distinguish costs incremental to *interconnection* from costs of improving service quality *within* a network. An especially difficult issue is distinguishing costs incremental to interconnection from those incremental to increased traffic volume. We believe the correct approach to resolving this problem is to recognize that the level of call blocking that subscribers experience is a key element of service quality. Increased traffic volume increases call blocking unless the network is adequately provisioned to be non-blocking. In order to distinguish between costs incremental to interconnection and costs incremental to intra-network service quality, we must now drop our assumption that all networks are fully provisioned to be non-blocking.

A. Interconnection between networks of differing service quality levels

43. In Figure 7a, we show two networks that offer differing service quality levels. The X network offers a lower quality of service. It is not fully provisioned, having provided only one

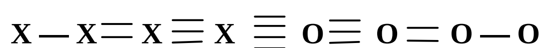
Figure 7a: Network X is not fully provisioned

X—X—X—X   O — O ═ O — O

urlink across its center. As a result, call blocking will occur whenever more than one X subscriber attempts a call across the X network's center. Network X is offering something loosely resembling old-fashioned party line service, serving four subscribers using only three urlinks at an average cost of ¾ urlink per subscriber. The O network, in contrast, is fully provisioned. O has an average cost of 1 urlink per subscriber and offers completely non-blocking service. In a competitive market, we can presume Network X's lower quality is offered at a lower price.[51]

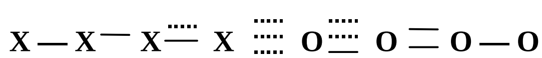
44. To see the incremental cost of interconnection in this case, it is helpful first to see what should *not* be included. In Figure 7b, the networks have interconnected *and* the X network (perhaps for competitive reasons) has added its missing link to become fully non-blocking. The total number of urlinks added is nine (and the maximum number of possible simultaneous calls across the centers of the networks has increased from three to four). If all nine added links were considered incremental to interconnection, then the X network would have 3 + 4.5 = 7.5 urlinks, or 1.875 per subscriber. The O network would have 4 + 4.5 = 8.5 urlinks, or 2.125 per subscriber. This cost assignment gives X an artificial advantage because one of its intra-network links is

Exhibit 7b. Fully provisioned interconnection of non-blocking networks



being included in the cost of interconnection. X can now offer the same calling list and the same quality of service as O, but at a lower price. O subscribers are paying a "tax"[52] of 0.125 urlinks in order to subsidize X subscribers. Recognizing that X added this second link across its center to upgrade its intra-network service quality, rather than for interconnection *per se*, eliminates this artificial advantage.

Figure 7c: Interconnection when X remains less than fully provisioned



Dotted lines represent links incremental to interconnection.

45. As a further illustration of this point, suppose the X and O networks want to maintain their differing grades of service. In this case, only six incremental links (dotted in Figure 7c) are needed to maintain the O network's non-blocking grade of service while not reducing blocking (upgrading service) between X network subscribers. The other two interconnection links in Figure 7b can never be needed as long as X has only one link across its own center, because there can never be enough XO traffic to require their use.

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51 If we relax our assumption that all subscribers are identical, this result could be a stable outcome in that Network X attracts those who are willing to accept lower quality service in return for a lower price.

52 This term is used here not in its legal sense, but in the economic sense of a price above marginal cost.

46. Now we are ready to illustrate our point about distinguishing between interconnection and intra-network service quality. After interconnection in Figure 7c, the maximum number of possible simultaneous conversations possible between pairs of X network subscribers is unchanged. As before interconnection, only one conversation can cross X's center. Applying the BASICS Rule to the incremental links (there are six more urlinks than before interconnection in Figure 7a) assigns three more urlinks to X, for a total of six urlinks for four subscribers, or 1.5 urlinks per X subscriber. The four O subscribers now have 4 + 3 = 7 urlinks, or 1.75 per subscriber. Note that the O network again has more links per customer and a higher quality of service (zero intra-network call blocking) than the X network (where there is some blocking).[53] The point is that interconnection under the BASICS cost-assignment rule has not distorted the relationship between cost and service quality for the two networks.

47. Comparing Figures 7b and 7c also enables us to distinguish clearly between costs that are incremental to interconnection *per se* from those that are incremental to improving service quality *within* a network. In both cases, the O network is fully provisioned and will not experience any blocking whatsoever on O-O calls or on any calls that arrive from X. In 7c, however, the X network remains less than fully provisioned and does experience some internal blocking. Some calls from O subscribers to X subscribers may also be blocked, but blocking can only occur on calls to or from X subscribers. Costs of upgrading service quality for these X subscribers are not incremental to interconnection *per se*.

48. Figure 7c also helps highlight the distinction between interconnection and intra-network quality of service. Interconnection increases the number of parties that each subscriber is able to call. It does not directly affect possible call blocking *within* the interconnecting networks. Thus costs incurred to reduce call blocking that occurs entirely on one network are not costs incremental to interconnection, and would not be split between the networks. We are thus distinguishing between costs incremental to *traffic* and costs incremental to *interconnection*. We believe this analysis demonstrates that to achieve efficiency the former should be assigned to the separate networks and only the latter should be split (equally) between the two interconnecting networks.

49. Because this is such an important and potentially controversial point, let us illustrate the distinction between costs incremental to interconnection and those incremental to intra-network service quality from yet another perspective. It is possible that after interconnection X subscribers may wish to make more calls than before, because they can now reach more

[53] In fact, the average cost (price) difference is 0.25 urlinks, precisely as before interconnection. This can be understood as the premium O subscribers pay for a higher (non-blocking) quality of service. The fact that the difference is precisely unchanged depends on the assumption that the two networks are of equal size. In the more general case, the magnitude of the difference might change, but the direction would not (the more expensive network would remain more expensive, thus a quality premium would remain).

parties.[54] If this increased demand causes X to provision its internal links fully (by adding the second link across its own center), the total number of possible calls across X's center increases from one to two. Thus Network X becomes fully non-blocking. If it adds this second center-link, Network X has the same cost (7/4 = 1.75 links per subscriber) and the same quality of service as O. The added link may be seen as incremental to *traffic volume*, or to service quality within X, but it is *not incremental to interconnection per se*. We believe this is a highly significant distinction that is essential to getting interconnection policy right, that is, to finding an efficient rule for assigning interconnection costs.

Figure 7d: Making interconnection non-blocking once both networks are non-blocking

X — X = X ≡ X ≡ O = O = O — O

After X adds a second link across its own center, the two dotted links can be added to Figure 7c to make interconnection completely non-blocking

50. Notice, furthermore, that once X has fully provisioned its internal network, the networks may now want to add two more interconnection links (dotted in Figure 7d). These two links would have been redundant without the second link across X's center, but they now improve quality of service (reduce blocking) on inter-network calls. Note also that these two links are needed only to preclude blocking of inter-network, not intra-network, calls. They can never be needed for intra-network calls.[55] Under BASICS each network would pay for half these additional inter-network links, and each would end up with 8/4 = 2.0 urlinks per subscriber. Thus, once both individual networks are internally non-blocking, fully non-blocking interconnection means adding a total of eight links (the six dotted in Figure 7c plus the two dotted in 7d). These eight links are incremental to interconnection, but the second link across the center of X is not incremental to interconnection.

51. We should also note at this point that, although our diagrams do not make this obvious, the interconnection links differ from the internal links in that they are needed only to carry inter-network traffic. They can never be needed for intra-network traffic. More importantly, they are inter-office links rather than loops (links between end offices and end users). This distinction may be significant when networks use differing loop technologies. Inter-network links today, and almost all inter-office links, are likely to be optical fiber links.[56] If one or both of the individual networks uses a different technology, for example, wireless, its *internal* links may be more expensive. The analysis we have developed thus far suggests that only the

[54] That is, we would expect the demand for calls to be a function of, among other things, the number of parties who can be called.

[55] Recall that we are abstracting from designed redundancy in our simple network.

[56] Some "legacy" copper or microwave links have not yet been replaced.

costs of the (fiber) inter-network urlinks[57] should be split equally between the two networks.[58]

B. Does the BASICS Rule resolve quality of service externality problems?

52. Does a network's decision to offer a lower quality of service impose an externality on the interconnecting network? The answer, no, is already implicit in the discussion above comparing Figures 7b and 7c. This is such an important point, however, that it seems worthwhile to make it explicit. Figure 7c shows that any call blocking that results from under-provisioning links will occur on the network that under-provisions, not on the interconnecting network.

53. If we made some simple assumptions regarding calling preferences, we could calculate the expected call blockage suffered by subscribers to the degrading network and subscribers to the interconnecting network. Assuming that each subscriber is equally likely to try to call each other subscriber, we could show that the bulk of the call blockage would occur on the network that degrades its internal links.[59] The only blockage experienced by subscribers to the fully provisioning network is on inter-network calls to customers of the under-provisioned network. The network that under-provisions bears the main impact itself, and the other network is affected only on some inter-network calls.

C. Can Networks resolve the Network Externality under BASICS?

54. By focusing on inter-carrier compensation, we can also resolve serious externality problems and thus transform telecommunications markets into normal markets in the sense used

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[57] Recall that our urlinks include a bit of incremental switching capability. We believe this would amount only to a modest increase in switch memory (to accommodate larger look-up tables) and possibly a dash more processor. Our understanding is that rates for transport links (trunks) and entrance facilities include the switch rearrangements necessary to enable the switch to recognize and route calls to and from the links. In a dispute resolution, we would suggest that a regulator or arbitrator adopt the incremental-only costing approach that FCC applied in the Local Number Portability proceedings, which would explicitly reject any allocation to interconnection of the "common costs" of a switch. See In the Matter of Telephone Number Portability, Cost Classification Proceeding, CC Docket No. 95-116, In the Matter of Telephone Number Portability, *Third Report and Order*, 13 FCC Rcd 11701, 11740 (1998).

[58] We consider the case of differences in link costs in the next section.

[59] The algebra is reasonably straightforward, but somewhat tedious. That is, an economist with low opportunity costs could work it out on the back of a very large envelope, but few lawyers would be willing to follow it. These results do depend on making a strong assumption that expected call attempts are uniformly distributed. On the other hand, the most likely alternative to this assumption would be that subscribers are, if anything, somewhat more likely to call others on their own network. This is because networks are more likely than not to be formed initially among subscribers who share some community of interest (if only location). To the extent that intra-network calls are more prevalent, our results are strengthened.

by Brock,[60] that is, markets without externality problems. The current rules, in effect, create externalities, because buyers and sellers do not see the networks' actual costs, only averaged rates. If we can resolve these externalities, we share Brock's view that networks can successfully internalize the fundamental network externality that other subscribers also benefit when an additional party subscribes. The BASICS rule of splitting equally only those costs incremental to interconnection *per se*, internalizes those externalities caused by current institutional arrangements.

55. In less regulated telecommunications markets, such as for internet service provider (ISP) and wireless services, we frequently observe networks offering inducements to attract new subscribers. Because the network becomes more attractive as more subscribers sign up, we believe networks can successfully internalize the network externality, at least where regulatory restraints on pricing do not preclude this.

56. In unregulated communications markets, firms do use pricing strategies that seem to internalize the network externality. Newspapers and magazines, for example, face something similar to the network externality because their attractiveness to advertisers and even to other potential subscribers depends to a great extent on their number of subscribers. For this reason, newspapers often offer subscriptions at rates that appear to be below average cost and perhaps even below marginal cost, sometimes barely covering delivery cost.[61] This strategy seems to be profitable because it increases advertising revenues. Similarly, many ISPs offer below cost subscription or free E-mail service, apparently in order to increase sales of advertising. Web sites and broadcasters pursue a similar strategy of offering free information or entertainment in order to attract advertising revenues. These unregulated firms[62] appear to be using retail pricing strategies successfully to internalize externalities. Although we do not attempt to prove this formally, we believe networks may succeed in internalizing the network externality through similar strategies.

VI. CAN THESE RESULTS BE GENERALIZED?

A. Does BASICS work for networks of other than linear form?

57. We believe these results can be generalized, although we must offer an important caveat. In our analysis above, we abstracted from such engineering considerations as scale economies and trunking efficiencies. We believe this is a reasonable abstraction because, as noted above, we assume that each network has access to the same underlying technological possibility set and to equally skillful engineers. Although we express our results in terms of cost

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[60] That is, markets without externalities. Gerald W. Brock, "Interconnection and Mutual Compensation with Partial Competition," p. 10, in Brock (1995), fn 4 *supra.*

[61] "Introductory" rates for new subscribers are often even lower. In this case, however, the firm may hope to retain the new subscriber as a long term customer, a slightly different motivation.

[62] Broadcasters are, of course, regulated in several ways, but their pricing is generally unregulated.

per subscriber, it would be more accurate to say "urlink burden per subscriber," referring to our abstract measure of interoffice link or switching capacity. A more general expression of our results would not be that the BASICS rule equalizes per subscriber *cost*, but rather that it equalizes the raw, underlying per subscriber burden due to interconnection. Our point is that interconnection does not distort the underlying, pre-interconnection cost relationship. Each network enjoys whatever scale or scope economies its engineers can find, employs whatever technology it chooses, and faces the resulting costs. A BASICS rule simply does not distort whatever cost relationships would have existed without interconnection, and does not distort carrier decisions. In this sense, BASICS is a competitively neutral cost allocation rule.

58. The key mathematical relationship upon which our results above depend is that, for the simple networks we examined, splitting equally the incremental costs of interconnection yields the same cost per subscriber for each of the interconnecting networks. With the caveat noted above, we believe that if this relationship holds for other network forms, then our other results also follow.

59. The BASICS results do hold for mesh type networks. Unfortunately, a graphical depiction of a mesh of more than a very few subscribers or nodes exceeds our skill level. Fortunately, the algebra is no more complex than that for linear networks, so we can show this result algebraically.[63] The basic difference is that the number of urlinks required for a mesh network is $(n^2-n)/2$ (the standard formula for combinations of two in a population of n) rather than the $n^2/4$ of a linear network.

60. The BASICS rule also holds for a network composed of a fiber optic ring connecting central offices, if we make a simplifying assumption. It does not matter how the various central offices are configured, other than that each network should have the same average number of subscribers per central office. We address the reasonableness of this assumption below. Once again the algebra is fairly simple,[64] and the BASICS rule produces the same burden

[63] Using the same variables and approach as for the linear network in footnotes [42ff] above, we find that the incremental urlinks required to combine a network of a subscribers with a network of b subscribers is, for mesh networks, ab. So each network would be responsible for half, $ab/2$. Network X starts with $(a^2-a)/2$ links and adds $ab/2$. Dividing by a subscribers produces an average urlink "cost" of $(a^2 - a - ab)/2a$, which reduces to $(a + b - 1)/2$. Similarly, Network O begins with $(b^2-b)/2$ urlinks and adds $ab/2$. Dividing by b subscribers produces $(b^2 - b + ab)/2b$. This reduces, again, to $(a + b - 1)/2$.

[64] Imagine a constellation of central offices connected by a fiber optic ring. The total number of subscribers (sum of all central offices) is n. The average size of a central office is s subscribers. In order to be non-blocking, the "width" of the ring has to be n (a ring has built-in redundancy for reliability). Thus the number of central offices is n/s. The number of urlinks needed to make up the ring is $(n)(n/s) = n^2/s$.

Now suppose two networks of central offices interconnect. The total numbers of subscribers on the networks are a and b, respectively. Assuming s is the same for each network, the networks begin with a^2/s and b^2/s links respectively. The incremental ring-links are the difference between the requirement before and after interconnection, or $(a+b)^2/s - a^2/s - b^2/s = 2ab/s$. If we split this number equally, each (in urlinks per subscriber) for each network after interconnection.

61. Viewed with a reasonable degree of abstraction, almost any network configuration can be resolved into a combination of the linear, mesh and ring forms.[65] Although we do not attempt here a formal proof of this point,[66] we argue that one can make a strong intuitive case that our results can be extended to most if not all real world network configurations. We conclude tentatively that, arguing by analogy, the basic principles we have discovered here are robust. That is, the BASICS rule is administratively simple and produces an efficient assignment of interconnection costs between the two networks.

B. What if the subscribers are actually central offices?

62. The assumption immediately above for ring networks that both interconnectors have central offices of the same average size seems rather strong, but we believe it is not nearly so unreasonable as it may first appear. This point is worth exploring, because it applies to other network forms as well. Even our simple linear networks implicitly assume that, if the Xs and Os are actually central offices rather than individuals, they are of the same size.

63. We believe our equal average size assumption is reasonable because our analysis depends on viewing interconnection at the same level of line concentration. All our analyses take place at the same lowest common denominator, in the sense that we analyze a very large switch as a combination of smaller ones. That is, we view a large central office as equivalent to several smaller ones that are linked together. Thus a large central office requires internal links among its components. We think this is a network topology question for engineers to optimize, not a question of underlying urlink burden. The engineers determine the optimum combination of switching and links to meet the urlink requirement. We recognize that scale economies and network efficiencies occur, but we assume that each network does have access to equally brilliant engineers and to the same technology set. We are only concerned that each interconnecting network bears the same "urlink burden," that is, the same underlying raw capacity requirement

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network is responsible for ab/s additional $_{ur}$links. So the number of $_{ur}$links for the first network is now a^2/s + ab/s and its average $_{ur}$links per subscriber is $(a^2 + ab)/a$s = $(a + b)$/s. For the second network, the number of $_{ur}$links is now b^2/s + ab/s and its average $_{ur}$links persubscriber is $(b^2 + ab)/b$s. This reduces again to $(a + b)$/s.

[65] Another common network form is the "star," in which there is one link (loop) from each subscriber to the central office. We view this simply as an engineering solution that provisions the basic, underlying urlink requirement by employing more switching and fewer links. All the switching is concentrated in the central office. Star networks have desirable efficiency properties under some circumstances, but their geographic size is limited by their need for longer links as the service area expands. As "constellations" of stars are linked into a larger network, the results resemble a linear, mesh or ring network, depending on just how they are linked.

[66] The problem is that, while we can represent urlink requirements for simple network types mathematically, we are not sure how to represent the requirements for a generalized network.

per subscriber, not with the manner in which its engineers provision this burden.

64. We could allow subscriber (i.e. central office) sizes to vary. The mathematical treatment would become much more complex. Urlinks would become erlangs, that is, we would have to take explicit account of circuit demands. The analysis would become much more complex, but we believe the essential results would not change. We do not, however, attempt to prove this assertion formally in the present paper.

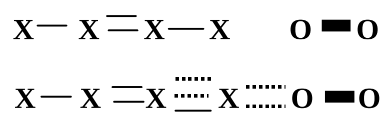
C. What if the networks have differing link costs, or subscribers have differing preferences?

65. The case of differing link costs is the exception that proves the rule. Here, the BASICS rule will not produce equal urlink/subscriber burdens, but rather preserves the pre-interconnection relationship. It does not distort subscriber choices.

Figure 8: Interconnection of a 4-party network and a 2-party network with differing costs

8a:

8b:



The heavier O-O link costs ten times as much as an X-X link.

66. As a simple illustration, let us recall the interconnection example of Figure 6; but in Figure 8 let the heavy O-O link cost as much as 10 ordinary links. O offers premium service characteristics (perhaps mobility) at a premium price. Before interconnection, the average cost for Network X is 1.0 (urlinks per subscriber). O's average cost is 5.0 (one expensive link shared by two subscribers). Interconnection requires four incremental links, which are ordinary links.[67] After interconnection, each network is responsible for two (half of four) incremental links. X's average cost rises to (4 + 2)/4 or 1.5. O's rises to (10 + 2)/2, or 6.0. The pre-interconnection cost relationship remains: O offers a premium service at a higher price. The BASICS rule has not distorted this relationship.

67. It is useful to break down the costs in this illustration between intra-network and

[67] Recall that virtually all inter-network transport today is provisioned by optical fiber, regardless of the technology of the interconnecting networks. Even between two wireless networks, interconnection is generally via fiber links. Thus the costs that are purely incremental to interconnection are generally independent of the internal technologies of the interconnecting networks.

interconnection services. X subscribers pay[68] 1.0 urlink each for access to other X subscribers and 0.5 (0.25 x 2) for access to the two O subscribers. O subscribers pay 5.0 for premium access to other O subscribers and 1.0 (0.25 x 4) for access to the four X subscribers. Each X or O subscriber pays (in this example) ¼ urlink in interconnection costs for each additional party it can call as a result of interconnection. X subscribers do not pay any more or less for access to other X subscribers than before interconnection. The same is true for O subscribers. The point is that neither network subsidizes the other. BASICS does not distort subscriber choices.

68. In a world in which various types of networks are possible, it is important that each network recover its intra-network costs from its own subscribers. Not all subscribers have identical preferences regarding technology, service quality, additional features, price and other aspects of network offerings. A single package is not likely to be optimal for every individual subscriber. Some subscribers may place a premium on very high reliability while others may accept occasional blockage, reduced voice or data quality, or even occasional outages in exchange for a lower price. Likewise, some subscribers may be willing to pay for the benefits of mobility offered by certain technologies, while others may forego mobility in return for a lower price. Some subscribers may choose a lower monthly charge plus a usage charge, while others may prefer a higher monthly charge that includes unlimited usage. Splitting equally the costs that are purely incremental to interconnection and requiring each network to recover its intra-network costs from its own subscribers permits each network to offer retail packages and each subscriber to choose the combination of features and price that best suits her preferences without distortions caused by cross-subsidization.

VII. INTERCONNECTION WITH A DOMINANT CARRIER

69. Interconnection with a dominant carrier is the one case in which we need to discuss retail pricing arrangements in the present paper. Where there is no dominant carrier, we have argued that retail pricing can (and in fact must) be treated separately from interconnection, and that a regulator need not be concerned with the manner in which carriers structure their retail offerings. In such a case, competitive market forces will assure efficient results.[69] As discussed in Section III above, however, a dominant carrier may be able to exploit its market power by discriminating between on-network and off-network calls. Such discrimination might enable the dominant carrier either to deter competitive entry or to exploit a network in a related market. It may therefore be necessary to prevent a dominant carrier from engaging in such discrimination.

70. We believe the remedy for possible discrimination by a dominant LEC is to grant

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[68] For convenience we assume here that the networks are pricing at average cost, even though it would be more accurate to say that the networks are bearing these per-subscriber burdens and recovering them in some unspecified manner.

[69] See Gerald W. Brock, “Price Structure Issues in Interconnection Fees,” in Brock (1995), fn 4 *supra*; and *Policy and Rules Concerning Rates for Competitive Common Carrier Services and Facilities Authorizations Therefor*, First Report and Order, 85 FCC 2d 1, 31-35 (1980) (discussing reasons it is unnecessary to regulate the rates of non-dominant carriers).

interconnectors a right to non-discriminatory treatment within whatever local calling area the dominant LEC has established. An interconnecting LEC located within the dominant LEC's local calling area, upon fulfilling the BASICS requirement of splitting incremental costs of interconnection, would have the right to have its traffic treated on the same basis as the dominant LEC's own local traffic. That is, the dominant LEC could not discriminate between on-net and off-net calls within its local calling area.

71. Similarly, an out of area carrier (a LEC or an IXC) would be entitled to non-discriminatory treatment if it provides all the transport to (and from) a point within the local calling area of the dominant LEC plus the usual BASICS requirement of half the (local) incremental interconnection costs. If the out of area carrier bears these costs, a local dominant LEC would be obligated to treat inter-carrier calls in the same manner as it treats other local calls. The out of area carrier would, of course, be free to charge end users (but not other carriers) for the transport into the local area in any manner it chose, as long as it is not a dominant carrier.

72. Interconnecting networks in different local calling areas could also agree to split the cost of the transport between their local calling areas. If they did so, both networks would remain free to impose a toll (per-minute fee) or other fee on end users for their use, if they chose to do so. If the networks do not agree, however, a non-dominant carrier would have the right to demand that a dominant LEC allow it to provide the transport into the local calling area, interconnect on a BASICS basis, and have its traffic be treated on a non-discriminatory basis.

73. We do not discuss in this paper the separable question of whether recovery would be from calling parties, called parties, or both. What BASICS would preclude, however, is one network charging the other network for local interconnection, except to the extent that they split capacity costs incremental to local interconnection (or mutually agree to another arrangement).

VIII. A BRIEF COMPARISON OF BASICS TO CURRENT INTERCONNECTION REGIMES

74. A bill and keep regime patterned after the BASICs rules solves several problems that are inherent in access charges, reciprocal compensation and international settlements. First, such a regime eliminates the ability of a network to shifts costs from its subscribers to another network. A network can recover its costs from another network's subscribers only to the extent each of those subscribers is willing to accept its charges. By eliminating the intrinsic monopoly of access, reciprocal compensation and settlements, it also eliminates the chief theoretical justification for rate-regulating inter-carrier compensation.

75. Second, forcing networks to bear their own costs has many efficiency ramifications. Subscribers and networks, through their subscription and entry decisions, control the costs they bear. Under access charges a network recovers only a fraction of its costs from its own subscribers. Under reciprocal compensation and international settlements, a network's costs are an average of many networks. Under bill and keep, a network's costs are determined by its own decisions.

76. Third, a bill and keep regime greatly reduces the artificial arbitrage opportunities

by giving customers the correct market signals about whether to build a network and interconnect, or to subscribe to an existing network. Under access charges, much traffic has moved off the public switched network on to private special access networks. The ESP exemption allows enhanced service providers to interconnect with local networks as subscribers and thus avoid being penalized by the high access charges imposed on IXCs.

77. Fourth, by eliminating the emphasis on the direction of the flow of traffic between networks, bill and keep reduces the incentives of customers to artificially organize traffic into one-way flows. For example, under reciprocal compensation, new networks had a strong incentive to seek out customers that only received calls. Under settlements, call-back schemes proliferated.

78. Finally, although access, reciprocal compensation and settlements do not necessarily lead to artificial per-minute costs being created on interconnecting networks, as a practical matter they have inevitably transmuted what are capacity costs on one network into real per-minute costs on interconnecting networks. It seems fair to say that the Internet would not be what it is today if Internet service providers had had a per-minute cost structure imposed on them.

79. The access charge regime, of course, was not intended to achieve economic efficiency. It was designed to transfer subsidies from IXCs (or their customers) to local carriers, in order to reduce local rates.[70] The stated primary purpose was to increase penetration, i.e. the percentage of the population that subscribed to telephone service, and thus promote universal service. Today, penetration is very high except in certain very limited areas.[71] More importantly, the Telecommunications Act of 1996 directed that support for universal service no longer be provided through cross-subsidies.[72] Now that the statute has directed that its primary purpose should be accomplished by other means, there is no longer an over-riding justification for enduring the inefficiencies of the access charge regime.

80. The reciprocal compensation regime differs from the access charge regime in degree rather than in principle. It may be thought of simply as symmetric access charges. The principal difference is that reciprocal compensation rates are not explicitly intended to transfer substantial subsidies to the terminating carrier, thus they tend to be much lower than access charges. On the other hand, reciprocal compensation applies to local rather than long distance traffic, so these rates are applied to many more minutes than are access rates. From a BASICS viewpoint, the costs of terminating calls should not be included in reciprocal compensation rates. Furthermore, as with access charges, direction of traffic flow is irrelevant from a BASICS perspective. The BASICS rule would yield much greater efficiency than a reciprocal

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70 See Brock (1994), fn 7 *supra*, especially chapter ten.

71 See FCC, *Universal Service Monitoring Report*, CC Docket No. 98-202, September 2000, Section 6.

72 47 USC 254(b)(5).

compensation system.

81. The current system of international settlements is based on the same broad approach as access charges. That is, the terminating carrier is compensated not only for the incremental costs of interconnection, but also for local termination of international calls. The monopoly carrier in other countries often sets the settlement rates at very high levels, thus aggravating the resulting inefficiency.

82. Of the current access regimes, the ESP exemption is the closest to BASICS in that it allows Enhanced Service Providers to interconnect with LECs by subscribing as end users. Under the right circumstances, as noted above, (mutual) subscription is approximately equivalent to a BASICS solution.[73] This solution to potential carrier market dominance in these potentially competitive markets was generated in the FCC's Computer Trilogy orders. Allowing carriers to interconnect on a subscription basis appear to be a useful approximation to a BASICS solution.

83. Technological developments are making it more attractive and easier for subscribers to exploit arbitrage opportunities offered by the differences among these various interconnection regimes. The use of Internet-based E-mail has already enabled many users to avoid (bypass) use of long distance voice services that are priced substantially above costs by substituting a similar, though not identical, service. The ESP exemption and reciprocal compensation rules favor flat rated (unlimited usage) pricing of ISP services.[74] At the same time, Internet interconnection closely resembles a BASICS rule. These factors already make E-mail a very low cost alternative to voice services and thus encourage customers to substitute away from long distance calls.

84. The ongoing improvement of the quality of Internet Protocol (IP) Telephony may greatly exacerbate the trend away from traditional long distance voice services. For the same reasons described in the previous paragraph, users are able to exploit the arbitrage opportunities offered by the differences among the access charge, reciprocal compensation and ESP exemption regimes. As IP telephony improves, this movement away from long distance can be expected to intensify.

85. These developments make the replacement of inconsistent interconnection regimes very desirable from the viewpoint of economic efficiency and regulatory simplicity. They may also be desirable to firms that cannot be sure how future developments will interact with the inconsistent regimes. Other future technological developments, whose natures are unknown at this time, may have substantial additional impacts as long as there are several inconsistent interconnection regimes. E-mail and IP Telephony are technological developments

[73] See paragraph 35 above.

[74] The ESP exemption prevents carriers from charging per minute access charges on ISP traffic. The reciprocal compensation rules encourage competitive LECs, in particular, to offer attractive terms to ISPs who will attract large volumes of terminating traffic, and thus large amounts of revenue, from incumbent LECs.

that have appeared suddenly, having become significant only in the past five years. Other problems are arising as the concept of access charges is extended to carriers with very different costs. Substantial "arbitrage opportunities" generated by differences in current interconnection regimes are inducing inventors and entrepreneurs to find new ways of providing services. These developments can be highly beneficial. To the extent they are motivated by differences in regulatory rules applying to various types of interconnection, however, they can also result in substantial inefficiencies and disruptions. A BASICS interconnection regime could replace all current interconnection regimes with a simple, efficient solution and offer the benefits of consistent treatment of all inter-network interconnection.

IX. POLICY CONSIDERATIONS THAT PRECLUDED BASICS-LIKE PROPOSALS IN THE PAST MAY NO LONGER APPLY

86. The history of interconnection policy suggests that a BASICS rule is not a radical departure from precedent, and that considerations that precluded its adoption in the past may no longer hold. As Brock explains, the very first competitive entry into retail long distance service relied on interconnection on a basis that is very close to a BASICS rule. In the mid-1970s, MCI initially obtained interconnection by subscribing to local business line service on both ends of MCI's inter-city transport link.[75] As we noted above, at least for simple networks, subscription is equivalent to a BASICS interconnection rule.[76] AT&T responded by creating special, higher, interconnection rates, which regulators permitted in order to protect the subsidies included in long distance rates.[77]

87. When AT&T began implementing discriminatory rates for interconnection, the interim rates were capacity based.[78] This is a rough approximation to a BASICS rule, under which carriers split incremental capacity costs equally, although the rates were set above cost to preserve the subsidy.

88. DOJ considered long distance service analogous to CPE. When the AT&T Divestiture was being negotiated, DOJ's theory was that long distance (i.e. interconnection) should be separated from local service.[79] This is our conclusion as well. In discussing financial arrangements between the new companies, Brock notes that "the simplest solution [to

[75] Brock (1994), fn 7 *supra*, pp. 124-127.

[76] See discussion at paragraph 35 above. This is a bit of an oversimplification, of course, in that subscription typically includes services that may be bundled and that may not be useful to an interconnecting carrier.

[77] This is a highly simplified summary of a rather complex discussion in Brock (1994), fn 7 *supra*, chapter 8.

[78] These were the initial Exchange Network Facilities for Interstate Access (ENFIA) rates. See Brock (1994), fn 7 *supra*, p. 142.

[79] Brock (1994), fn 7 *supra*, p. 175.

interconnection] would have been to follow the CPE model and allow any long distance company to connect to any local service with no payment other than the established local service charge."[80] This is, of course, equivalent to interconnection by subscription, thus very similar to the BASICS proposal. This proposal was not adopted because it would have "eliminated the complex set of payments among telephone companies …"[81]

89. In his 1995 paper, Brock also points out that a BASICS-like rule would resolve interconnection problems and produce an efficient solution compatible with competition. Brock's results, however, depend on balanced traffic or negligible termination costs. Our analysis above extends this proposal more generally by showing that traffic flow and termination costs are irrelevant.

90. BASICS resembles previous proposals and the earliest experience with competitive interconnection. The primary reason that these previous proposals were not adopted was the driving policy objective of protecting subsidy flows to local carriers. This objective has been removed by the 1996 Act. BASICS should now be considered as a replacement for all current interconnection regimes.

[80] Brock (1994), fn 7 *supra*, p. 176.

[81] Brock (1994), fn 7 *supra*, p. 176.

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