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Beyond spectrum auctions

Taking the next step to open spectrum access

Eli Noam

While the current system of auctioning exclusive licences may be the best way to allocate new frequencies for today, spectrum auctions may soon become technologically obsolete, economically inefficient, and legally unconstitutional. An alternative is to step beyond the current paradigm of licensed exclusivity to a system of full openness of entry. This would allow access to spectrum bands through access fees that are determined by demand and supply conditions at the time. Prices for access would vary, depending on congestion. Long-term access at a certain price could be obtained by using a futures market. Such a system converts fixed costs of entry into marginal costs of usage, and removes incentives for collusive pricing. © 1997 Elsevier Science Ltd.

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Three old paradigms and a new one

It will not be long, historically speaking, before spectrum auctions may become technologically obsolete, economically inefficient, and legally unconstitutional.

And it may not be long before a new form of frequency allocation may emerge where spectrum use does not require any licence; when information traverses the air as flexibly as an airplane in the sky, instead of being straight-jacketed into a single frequency and routed like a train on a track; and where congestion is avoided not by the exclusivity of ownership but by access charges that vary with congestion, with the information itself paying for access with tokens it carries along.

For today, auctions and usage flexibility are still the best way to allocate new frequencies. Yet it is one thing to support them pragmatically, as I do, because they tend at present to be a better approach than the existing alternatives, and quite another thing to behold them in dogmatic awe, blind to their technological relativism and economic limitations. Change the technology, and the economics and policy of spectrum use must change, too.

What we have in spectrum allocation is a classic case of a paradigm shift, along the lines of Thomas Kuhn's famous essay on the rise and fall of schools of thought.[1]

For spectrum, we can distinguish three successive paradigms, and an emerging fourth one. In the beginning, there was a brief idyllic stage of spectrum allocation based on *occupancy*. Entry to the virginal 'ether' was free. Early radio users did not think in terms of permits to spectrum access any more than the Wright brothers considered filing a flight plan at Kitty Hawk. Radio amateurs, early private broadcasters, radio telegraph operators, and the US Navy all congregated on the air. Given the rudimentary

technology of separation, and with only a few bands under technological mastery, it was not surprising that transmissions soon collided.

This inevitable crisis in the occupancy model led to the *administrative* paradigm. Frequencies were allocated by the state. A sparse civilian residual was allotted to various purposes and assigned to private firms based on a combination of first-come and best-connected. On the whole, this was a system that benefited influence brokers, bureaucrats who could gain off-budget degrees of freedom, governments which gained control over content, and incumbent firms that liked state-administered barriers to new entry. This became the orthodoxy—prosperous, powerful, potent.

But the problem was that the system did not work very well. Fights over allocations became shrill.[2] Competitors were excluded.[3] Foreigners were barred. New technologies were excluded or delayed.[4] Politics intervened hamfistedly.[5] Spectrum bands were utilized unevenly and inflexibly. Governments hogged vast stretches. Scarce licences became highly valued, and fortunes were made in the reselling of licences from the well-connected to the merely efficient. Some licences were loaded with requirements for off-budget public services. Licences were temporary in theory—discouraging investments—but permanent in practice—diluting the attached requirements.

The old administrative paradigm was in crisis.[6] Yet out of crisis, predictably, a new paradigm was born. And indeed, a new idea emerged, that of spectrum sales to the highest bidder, advocated first by a law student, Leo Herzel,[7] and then academic intellectuals, Ronald Coase[8] and later Arthur DeVany *et al.*[9] and Harvey Levin.[10] The idea was first dismissed out of hand as too 'academic', ridiculed as impractical by the FCC's former chief economist, the noted Dallas Smythe as "of the realm in which it is merely the fashion of economists to amuse themselves," and ignored or fought off by the established broadcasters.[11] Eventually, however, most economists adopted it. It then percolated to Washington think-tanks and some politicians. Change was in the air.

Today, the advocates of this *auction* paradigm are in the driver's seat. They have become the new conventional wisdom. And they are the darlings of the political establishment, providing it with vast new resources that make otherwise painful spending cuts or tax increases unnecessary. This is a heady experience for the dismal profession. But, just as Kuhn would have predicted, the new orthodoxy, too, has become complacent. Like generals fighting the last war, its adherents often reflexively oppose a questioning of the auction paradigm as a defense of the administrative model or of its beneficiaries, because that is where its opponents traditionally came from. Deep down, they believe, as Kuhn would have predicted, that their paradigm is the end of history in this field, and that there is no beyond. Any problems are viewed as mere aberrations, most likely because the auction concept is executed with insufficient purity, rather than due to a systemic weakness. In short, the auction has progressed from a better mousetrap to a belief system. This, too, is classic. And it is similarly classic that this will not endure, that a new paradigm will emerge in turn, and that its proponents will be ridiculed as impractical by yesterday's heretics.

The new paradigm is not based on exclusive use, the technological and economic foundation of both the administrative and auction paradigms. Indeed, both of these stages have much more in common with each other

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Mobeen Khan, and from other assistance from Mae Flordeliza, Anne Behk, and John E. Kollar. Helpful comments by Bruce Egan, Robert Frieden, John Friedman, Thomas Hazlett, Wayne Jett, Evan Kwerel, William Lehr, Terrence McGarty, Milton Mueller, Michael Noll, Jom Omura, Robert Pepper, Peter Pitsch, Ken Robinson, Aaron Rosston, Andrew Schwartzman, Nadine Strossen and John Williams are gratefully acknowledged.

[1]Kuhn, T S *The Structure of Scientific Revolutions* International Encyclopedia of Unified Science, Vol. 2, No. 2. University of Chicago Press, Chicago (1970).

[2]Former FCC Commissioner Glen Robinson described it as the FCC's version of Medieval trial by ordeal (McMillan, J 'Why auction the spectrum?' *Telecommunications Policy* 1995 **19**(3) 192–199.)

[3]The applicant for a fourth British radio licence was told in 1920 that "the ether is already full" (Briggs, A *The History of Broadcasting in the United Kingdom: The Birth of Broadcasting in the United Kingdom*, Vol. 1. London, Oxford University Press, Oxford (1961) p. 78).

[4]For the early history of FM radio, see Noam, E (ed) *Edwin Armstrong: A Man and His Inventions*, forthcoming.

[5]In the early 1950s, only newspaper companies that had editorially endorsed Eisenhower for President had a chance at getting a TV licence. Stevenson supports were left out. In other cases, politicians served themselves directly. For Senator Lyndon B. Johnson's personal enrichment from television licences, see Caro, R A *Years of Lyndon Johnson* Knopf, New York (1990); In France, the allocation of the third mobile licence was politically sensitive enough to be decided by Prime Minister Balladour personally.

[6]For a short while, it was substituted in the US by licence lotteries, a bizarre system that attracted almost half a million 'applications' out for a windfall.

[7]Herzel L. Public interest' and the market in color television regulation. *University of Chicago Law Review* **18:** 1951; 802–816.

[8]Coase, R 'The federal communication commission' *Journal of Law and Economics II* 1959 II 1–40.

[9]DeVany A S, Eckert R D, Meyers C J, O'Hara D, Scott R C. A property system approach to the electromagnetic spectrum: a legal-economic-engineering study. *Stanford Law Review* **21:** 1969; 1499–1561.

[10]Levin, H J *The Invisible Resource-Use and Regulation of the Radio* Johns Hopkins University Press, Baltimore (1971).

[11]Smythe D W. Facing facts about the broadcasting business. *University of Chicago Law Review* **20:** 1952; 100.

than their proponents would like to admit. Both basically allocate exclusive slices of the spectrum rainbow, and differ only in the early mechanics of that allocation. Seen thus, these two paradigms really collapse into a single one, that of *licensed exclusivity*.

But now, new technologies, available or emerging, make new ways of thinking about spectrum use possible that are more daring. The new paradigm is that of *open access*, in which many users of various radio-based applications can enter spectrum bands without an exclusive licence to any slice of spectrum, by buying access tokens whose price varies with congestion. These tokens could be carried by the information itself. This brings us back, in several ways, to the earliest stage of frequency use, where there were no licences. It is possible to do so because soon we can solve in new ways the problem of interference that had doomed the occupancy model and led to the licensing system in the first place.

The rumblings against the auction paradigm emerged in the mid 1990s by Paul Baran and George Gilder.[12] Underlying these views was the hope that technology solves scarcity and spares much of the need to deal with allocation questions. This is not my position.[13] With open access, scarcity emerges, the resource needs to be allocated, and a price mechanism becomes essential. Technology is not enough.[14] But this does not require exclusive control over a slice of the rainbow.

Whose spectrum is it anyway?

The emergence of technologies that allow multiple users of spectrum to cohabit and move around frequencies has important effects. They permit not just a more efficient system in terms of technology, economics, and policy. On these points one can disagree. But, it is also constitutionally the stronger system. Electronic speech is protected in the US by the First Amendment. Therefore, the state may abridge it only, according to established case law, in pursuance of a "compelling state interest" and through the "least restrictive means" that "must be carefully tailored to achieve such interest".[15] A licensing scheme, however conceived, is a serious restriction on speech. It forecloses the electronic speech of those without a licence and puts conditions on the speech of those with it. Until now, government licensing could be justified due to the basic assumption that it prevented collision of users. Some allocation scheme was therefore in order. But suppose that assumption becomes invalid? Would not the entire licensing scheme then be subject to question, in the same way that changing transmission technologies in cable TV and computer networking have led to lower levels of constitutionally permissible restrictions than for 'scarce' broadcasting?[16]

Is the spectrum the government's to sell in the first place? It is one thing to be a traffic cop, keeping the different users from colliding into each other. But it is quite another matter to assert ownership rights (in effect, to retroactively nationalize the spectrum) and to sell it off.[17] Could the state sell off the right to the color red if its use did not collide with others? Imagine the government auctioning off, all for perfectly good public policy reasons, the right to travel to Los Angeles (in order to prevent overpopulation), to print books (to protect forests), or to practice medicine (to keep down the cost of health care). Imagine, too, that these auctions are driven by the revenue needs of the state.

[12]Baran, P Is the UHF Frequency Shortage a Self Made Problem?, Unpublished paper, presented at the Marconi Centennial Symposium, Bologna, Italy, 1995; Gilder, G 'Auctioning the Airways' *Forbes*, 11 April, 1994.

[13]Noam, E 'Taking the next step beyond spectrum auctions: open spectrum access' *IEEE Communications Magazine* December 1995, 66–73.

[14]It is a similar problem of pricing necessity discussed for the presently 'free' Internet system as it is experiencing congestion problems (MacKie-Mason, J K and Varian, H 'Economic FAQs about the Internet' *Journal of Economic Perspectives* 1994 **8**(3) 75–96).

[15]*Sable Communications of California Inc. v. FCC*, 492 US 115, 109 S. Ct. 2829 and 106 L. Ed.2nd 93 (1989).

[16] *Turner Broadcasting System Inc. v. FCC*, 199 US Lexis 2078; 65 US LW 4208, 512 US 622, 129 L. Ed.2nd 497 and 114 S. Ct. 2445 (1994); *American Civil Liberties Union v. Reno*, 1996 US Dist. LEXIS 7919 (ED Penn. 1996). *Turner Broadcasting System Inc. v. FCC*, 1997 US Lexis 2078; 65 USLW 4208.

[17]Jett, W May God save the Constitution (With Our Help) From its Friends, unpublished paper, 1996.

Therefore, when less restrictive alternatives to licences become feasible, the government must abandon a restrictive spectrum access system. Regulatory powers do not convey the authority to government to appropriate the economic value from attractive commercial opportunities.

The future problems with auctions

Today, almost everyone loves auctions: most political liberals, because it makes business pay its way and generates government revenues; and most conservatives, because it substitutes market mechanisms for government controls. Auctions have been used in New Zealand, the US, the UK, Australia, Hungary, and India. Others will follow, no doubt.

The arguments for auctions are well-known. An auction is better than a mindless lottery, or than comparative administrative hearings with their inevitable and legal maneuvering. It takes politics out of the process. It gets spectrum resources quickly into the hands of users that value them highest. It rationalizes the assignment process while recovering the value of the spectrum to the public. It creates certainty and incentives to invest. Private auctions already exist in the form of a resale market.

The counter-arguments to auctions are also well-known. They are either those of existing stakeholders, of potential entrants who feel better served by the political process than the market, or of those who view spectrum as a public sphere subject to public goals. Broadcasters, for example, argue that the auctions should not extend to them, because they are required to perform public service obligations. An influential opposition comes from parts of the public-interest community which fears: (a) a decline in regulatory power over TV on behalf of public interest goals if renewable licences were replaced by permanent property rights; (b) that an allocation to the highest bidder would raise barriers to small entrants and reduce diversity; and (c) that auctions would squeeze out free public access and non-profit educational activities.

On the whole, the arguments in favour of auctions are stronger than the arguments against, partly because most legitimate problems raised by the critics can be dealt with in other and often more efficient ways. But this does not make auctions necessarily the best approach for the future.

Auctions inevitably deteriorate into revenue tools

The FCC auctions have been sophisticated in technical terms, well-executed as an operation, and based on game-theoretical models. The underlying objective for the auction 'game' is to raise revenues for government. This is usually denied quite heatedly, and various other considerations are cited, especially that of moving spectrum to the users valuing it most, etc. But the political fact is that auctions were approved, after years of opposition to them by powerful Congressional barons, as a measure to reduce the budget deficit and avoiding spending cuts and tax increases. Allocating spectrum resources efficiently was a secondary goal in the political process. The maximizing function may have been constrained in several ways, such as by rules against monopoly control and in favour of diversity. But these additional policy considerations were only the fig leaf on the main reason, raising money for the empty coffers of the Federal Government. The rest is merely technique. Conceived in the

original sin of budget politics rather than communications policy, spectrum auctions are doomed to serve as collection tools first and allocation mechanisms second.

Several problems are inexorably tied to the budget-driven auction system. One is a spend-as-you-go approach. It is one thing to sell assets (spectrum rights) and re-invest the proceeds. But the reality is one of funding current consumption through the sale of long-term assets. Around the world, countries aim to advance the national infrastructure. In the US, there seems to be a widespread agreement that this should be done without government money. But the spectrum sales end up as the opposite of making public investments. Auctions are taking money away from infrastructure—providing telecommunications firms and throwing it into the black hole of the budget deficit.[18]

In fairness, this is not due to the auctions *per se* but due to the way the revenues are being used by Congress and the Executive. Therefore, to maintain sectoral neutrality and avoid siphoning resources from the infrastructure into general public consumption, one would have to complement auctions with a recycling policy that returns the revenues to the communications infrastructure and its applications. But such an earmarking creates its own dynamic. For each spending program, stakeholder groups emerge and seek ongoing funding, and therefore ongoing auctions. Once a certain budgetary dependency on revenues from communications has been created, it will inevitably color substantive policy, such as by slowing the entry of new technologies if they threaten auction revenues. It may be an invisible tax on an invisible resource, but its impact on policy will be visible.

When all is said and done, an auction is a tax on the communications sector and its users.[19] Auction advocates deny this, arguing that consumer pricing depends on marginal rather than historic cost, and that the auction charge does not necessarily mean higher end user prices if demand is highly elastic or if the rents have previously been squeezed by government in other ways. It may be useful to start with a reality check. How can one possibly deny that the many billions of dollars raised by an auction are taken out of the private sector and end up with the government?

The argument is that an auction bid is a fixed cost and not part of short-term marginal cost, thereby not affecting price, and that all an auction does is reduce profits to a normal level. Only demand characteristics count. This view supposes that there are no alternative long-term uses for the spectrum and for capital. But since alternative uses for spectrum exists continuously, the supply of the service is not fixed and can expand and contract with its expected profitability. Similarly, alternative uses for capital exist. And greater indebtedness may mean higher cost of capital to a firm generally.[20] Firms may price temporarily according to short term marginal cost, but they could not survive doing so in the long run. Hence an auction payment will be reflected in prices, with its incidence on consumers and producers depending on the respective demand and supply elasticities.

And where is all this going to end? Like diamonds, budget pressures are forever. There is never enough money. This creates a dependence on still more auctions. Everybody will get into auctions, because everybody has an old budget deficit or a new funding proposal. There will be auctions everywhere, in any country in search of hard currency, and by international organizations.

[18]The short-term orientation of auction gains is also manifest in its accounting. Net revenues raised tend to be exaggerated because there is a trade-off between short-term revenue collection and long-term reduced tax yields. License payments can be depreciated against corporate income, and are also likely to reduce dividends. Under quite reasonable assumptions, each dollar of auction revenue tax is reduced by about 25 cents of reduced tax revenues in present value. And some revenue may never be collected as some of over-reaching bidders default.

[19]Concern with effects of auction on service prices was raised by the European Commission in a Green Paper, 'The liberalization of telecommunications, superstructure and cable television networks'. Commission of the European Union and DG (1994) p 26.

[20]McMillan *op cit* Ref 2.

It has been argued that at least auctions put a foreign government's decision process into the open, away from influence peddling and corruption, and that auctions thus play a liberalizing role in facilitating competition. This might be true in some cases, but the opposite to liberalization is just as likely. A revenue-strapped country is likely to sell off a monopoly licence rather than competitive ones, because this will fetch the highest bid price. The determination of the appropriate market structure therefore will provide ample opportunities for manipulative interventions. And the non-political nature of the auction can be easily undermined by various domestic preference systems,[21] such as requiring bidders to join up with favored local partners, or by requiring bidders to undergo an approval process.

Another problem is that private valuation, in terms of auction bids, do not necessarily reflect social value, because it omits negative (as well as positive) externalities, and also consumer surplus, i.e. the benefit to a consumer above the market price. For broadcasting, whose economics are convoluted because it sells audiences to advertisers rather than tickets to audiences, the surplus of social over private value has been estimated to be seven times as high as market price.[22] Advertising-supported 'free' broadcasting could be squeezed out by auctions since it is inefficient in collecting consumer surplus, in contrast to pay schemes such as pay-TV or mobile telephony. This would justify use specification in some cases. Ham amateur radio operation is another example. Its spectrum usage would not survive the free market any more than Central Park would.

Auctions encourage oligopoly

An auction payment that must be paid in advance is a barrier to entry, unless capital markets are perfect, which they are not. This especially affects small firms and unproven technologies that cannot find partners to share the risks. Therefore, an up-front payment will reduce the pool of entrants.

Advocates of auctions claim that they are neither a barrier to entry nor a tax, because they merely duplicate the past 'private' auctions of the after-market. What they seem to have in mind as an alternative to an auction is a lottery system with an after-market, which indeed creates windfalls, transaction costs, and delay. But suppose the alternative were not such an inefficient (though unfortunately real) system, but a merit-based comparative selection (e.g. based on an explicit scoring criteria and evaluated by an expert panel like a scientific grant proposal) coupled with a 10-year non-resale provision. (This is not the author's recommended solution, but at least it is a more sensible comparative yardstick to the auction than the lottery and resale system, against which most alternatives look good). Such a system would have lower entry costs since no bids would have to be paid for.

The highest potential auction bid would be the present value of monopoly rent. The winner's profits would be normal, but price would be at monopoly level. The FCC recognized this and auctioned off several PCS licences, not just one. This was wise, as well as administratively easy, but it is much harder to bar oligopolistic bids. The highest bidders will be those who can organize an oligopoly. This is facilitated by bidding consortia of companies which would otherwise be each other's natural competitors, and who collaborate under some rationale of synergy. Those

[21] In Canada, a 10% national preference.

[22] Noll, R, Peck, M J and McGowan, J J *Economic Aspects of Television Regulation* Brookings Institution, Washington DC (1973).

firms presently already holding market power under, e.g. the cellular duopoly, would bid highest to maintain it and its profit. And if precluded from bidding in their own territory, (as they are in a departure from the highest value user principle) they could try to do it by proxy or by mutual back-scratching with other firms similarly situated elsewhere.

Second, after the auction, the high bidders will collectively suffer from 'winner's curse' (winning bids unsustained by adequate profits) and, after some shake-out period, will collaborate, because otherwise they might not be able to support their bid price's cost. Already, some of the winning bidders in the US have been defaulting. 'Sunk cost' leads to passive acceptance only in competitive markets, and after the fact. Oligopolists, on the other hand, will attempt to raise prices in order to recover their bid price and more. This does not require an explicit agreement, just commonality of interest, and is therefore difficult to identify. Even with multiple service providers on the national level, there would be pressures for regional concentration to take place, similar to the dominance in the aviation industry by individual airlines of various hub cities.

Oligopoly can be attacked in several ways: by adding spectrum allocations, encouraging spectrum flexibility, imposing structural rules of ownership limitation, and using antitrust law. This is indeed FCC policy. However, ownership limitations are regulatory in nature, may conflict with potential efficiencies of scale, and are at tension with the stated goal of moving spectrum to the highest-value user. Additionally, such structural rules would limit the ability of exit by a spectrum holder from one usage to another, since such exit may well impermissibly concentrate the market in the departed service. Flexibility of entry, on the other hand, is an excellent way to protect against oligopoly. The present auctions do not permit such flexibility, though the FCC is seeking it. But it must be kept in mind that entry into B means exit from A. Thus, the FCC's policy in favor of spectrum flexibility may collide with its structural anti-oligopoly goals.

A better alternative: open spectrum access

The alternative to the present auctions is not to return to the wasteful lotteries or comparative administrative hearings of the past, but to take a further step forward, to full openness of entry, which becomes possible with fully digital communications. Auctions are mostly good for now, given the state of technology, but there is a better next step, a free-market alternative: an open entry spectrum system. In those bands to which it would apply, nobody would control any particular frequency. In this system no oligopoly can survive, because anyone can enter at any time. There is no licence, and no up-front spectrum auction. Instead, all users of those spectrum bands pay an access fee that is continuously and automatically determined by the demand and supply conditions at the time, i.e. by the existing congestion in various frequency bands. The system is run by clearinghouses of users.

The underlying present auction system is premised on the conventional but flawed analogy to land ownership (or long-term lease). This is based on a certain state of technology. In the past and present, the fixed nature of a frequency usage had a stability that is indeed reminiscent to land. But that was based on the relatively simple state of technology, in which information was coded (modulated) onto a single carrier wave frequency

or at most a narrow frequency range. To forestall interference with other information encoded on the same carrier wave, the spectrum was sliced up, allocated to different types of usages, and assigned to different users. It is as if a highway was divided into wide lanes for each type of usage-trucking, busing, touring, etc.—and then further into narrow lanes, one for each transportation company. Once one accepts this model for spectrum one can argue about how to distribute the lanes, whether by economics, politics, chance, priority, diversity, etc. But it is important not to take this model as given and focus one's attention on merely optimizing it. To stay with the example, why not intermingle the traffic of multiple users? And if the highway begins to fill up, charge a toll to every user? And make this toll depend on the congestion, so that it is higher at rush hour than at midnight?

Access rights are economically relevant only when there is scarcity. But absence of scarcity is not the interesting or usual case. Nobody 'owns' the air route. Cleveland-San Jose, and anybody could enter. But if landing slots or airport gates are scarce, an allocation must take place. In spectrum usage there are times of day and parts of the country where spectrum usage is always low. But it is realistic to assume that if there are multiple potential users and no restrictions, congestion will happen. To allocate access one need not grant permanent allocation rights, but rather to charge an access fee that is set at a level where the available capacity is fully utilized. Because demand for transmission capacity varies, the access fee would also vary—a high fee where demand is high, and zero when there is excess capacity.

The open access model

Technologically, the proposed system is not presently available, though its component parts exist or are within reach. It is not my purpose to try to work out the details here. They will evolve with time, discussion, and technology. What is important is the concept. Herzel and Coase did not design a multi-round simultaneous Vickrey auction, either.

Such an open access system might look as follows:

For packets of information to be transmittable, they would have to be accompanied by an access authorization code. Such a code could be a specialized token or a general electronic cash coin. The token would enable its bearer to access a spectrum band, to be retransmitted over physical network segments, and to be received in equipment. Prices for access would vary, depending on congestion. Assured long-term access at a price certain could be obtained by using a futures market.

The blocks of information carry these tokens with them, together with the address they seek, and pay (i.e. transfer tokens) at various toll gates and access points. The tokens are electronic coins that are transferred from user to carrier and the clearing house. They are like money. In effect, the information not only finds its own way (which packets already do), but also carries its own money for transit, picking among various over-the-air and wireline transmission options depending on price and performance. This resembles a person navigating a transportation system, choosing routes and transit modes, and paying along the way.

For example, a mobile communications provider, *A*, might expect heavy demand for its service during drive time. It would therefore buy access codes to the desired capacity and band. The tokens are bought

from an automatic clearinghouse of all users. Firm *A* and its customers, when initiating transmissions, add the access token to blocks of their transmitted information.

If *A* finds itself using less capacity than it needs, it can offer its excess access codes on the clearinghouse's spot market to users who experience shortages or who have no real-time needs. *A* can assure itself of a long-term supply by contracting in a future market for access codes with a dealer *B*, who then must deliver these codes at the time contracted for.

The buyer of capacity does not own any particular slice of spectrum, but rather the right to send so many information blocks over a band. A receiver, similarly, scans for information addressed to it. This is similar to the way computer local area networks work over wireline networks and now also over the air.

The clearinghouse could also auction off long-term access codes, as long blocks of usage time. In that case, it would approach the present auction and license system, except that no frequency-exclusivity needs to exist, though that could also be instituted.

The access codes are, in effect, like tokens paid by drivers at toll. They also resemble, in concept, the tokens used in 'token-ring' computer data local area networks architecture, where, in order to avoid congestion and collision of information streams, only that user can transmit bits who possesses a token that circulates from user to user.

How to implement an open spectrum system

Who would administer such an open access system? The options are: (a) the government-but this would create powers of control, together with potential administrative inefficiencies; (b) the private owner of the spectrum. This is discussed further below; or (c) the users themselves, by way of a clearinghouse that functions like an exchange.

In practical terms, a clearinghouse would be a computer that sets access prices based on demand. The resource it distributes is the spectrum endowment which it controls. The potential user of spectrum would use some intelligent software agent to deal with the clearinghouse. If the spectrum user is willing to pay the going price, it will receive some form of use authorization. Multiple clearinghouses for different bands are also possible and would provide competition.[23] The mechanism of a clearinghouse of providers has precedent. It is the way in which the FCC has dealt with relocation issues in the PCS bands, and it is a mainstay in the electric distribution of power.

Prices might be initially announced by a signal of spectrum price being sent out by the clearinghouse, based on supply and demand conditions. When capacity is underutilized at that price, the price drops, and an updated price signal is sent out. The reverse holds true if there is excess demand.[24] There could also be different prices for different frequency bands, because their different propagation characteristics differentiate their attractiveness.

Each user could apply its own standards and protocols, within general technical parameters of signal strength, etc., to avoid interference. Enforcement of the system is straightforward for those flows of information that are transferred across networks. Without authorization code, they could not flow. For non-network usage, the presence of

[23]Different frequencies have different characteristics, making them best suitable for certain types of applications, e.g. building penetration, the antenna size, cost of components, effects of atmospheric and climatic conditions, range, etc.

[24]The adjustment of demand could be facilitated by some packets that are coded with a reservation price. Usage that does not require real-time is thus likely to make room when demand spikes occur.

transmissions without access codes would be closely watched by their competitors for business and for spectrum access, and violators would be sued or reported.[25]

In some cases, a frequency would be entirely dedicated to a user or usage, based on special circumstances, for example, to protect non-profit, educational, or governmental usage. Alternatively, such users could receive a credit against which they could obtain access in the open-access system, and which they could resell.

Who gets the proceeds? That is a political decision of allocation. It could be the general Treasury (as in the auctions, and with a similar negative potential), or some earmarked functions. But the difference is that the revenue flow is smoothed, away from the one-shot deals, and that it does not use long-term assets for present consumption. Instead, the system converts fixed costs of entry into marginal costs of usage. It therefore has a stabilizing function, because prices based on marginal costs are otherwise potentially too low to cover total costs, and hence encourage collusive pricing. Transaction costs in an open access system may be larger than in a traditional spectrum assignment system, but that is true for any open economic system. The offset is increased utilization and efficiency. And, similar transaction costs would also exist if a spectrum of owners would resell frequencies in a private resale market. Similarly, the setting of technical specifications would be no more complex in a clearinghouse setting than in an ownership model, because a user could employ any technology subject only to general non-collision rules that are set by statute, common law, or agreement of the users. Such an agreement would have less collusive potential, given the transparency of the clearinghouse process open to all users.

Objections to open spectrum access

The concept of buying spectrum access as an input rather than owning a spectrum licence is unfamiliar and disturbing to users and policy-makers alike, and a number of objections are made, on the grounds of practicality, uncertainty, and property.

Skeptics may want to learn how Ronald Coase came to embrace the concept of spectrum auctions: when the FCC's Chief Economist and distinguished communications scholar, Dallas Smythe, published a refutation to Leo Herzel's auction proposal, Coase was left so unpersuaded by the best arguments marshaled against auctions that he became a convert.[26] Smythe, who rejected the auction as being, as mentioned before, "of the realm in which it is merely the fashion of the economists to amuse themselves" argued that auctions were of technically impractical, citing "intolerable interference on other channels unless the whole is carefully engineered...".[27]

Technological considerations

Open spectrum systems is not a technical reality yet, but the various building blocks for its implementation either exist or are subject to rapid technical advance.

(1) *Signal processing* has made enormous progress, suggesting a future in which radios become portable digital computers. 'Software radio'[28] shifts the processing of the signal beyond the receiver antenna in the equipment to be performed by first digitizing the received signal and

[25]Spectrum-agility would not dispossess existing frequency licensees. They would still have the assured right to their spectrum, at no charge (if such is the term of their licence). It might be possible, however, for others to use the frequencies, on a compensated access fee basis, at those times when they are not actually being used, or when such usage would not interfere, e.g. due to their low-power nature. Such reselling possibility also establishes a way to buy out existing licenced users.

[26]Hazlett, T 'The rationality of US regulation of the broadcast spectrum' *Journal of Law and Economics* 1990 XXXIII, 133–175.

[27]Smythe *op cit* Ref 11, p. 100.

[28]Mitola, J 'The software radio architecture' *IEEE Communications Magazine* May 1995, pp. 26–38.

then conducting all further processing like demodulation, filtering and detection in software-defined processing units rather than, as at present, through manipulations of the electronic signal within hard-wired systems. Intensive research is underway on this concept.

(2) The biggest challenge faced by such equipment is the present inadequacy of processing power required for the massive computations that are required to be performed in real time, especially for interactive communications like voice. But this processing bottleneck is being reduced rapidly and will, no doubt, be solved in time.[29]

(3) *Signaling*. Many radio applications do not function anymore as stand-alone and separate systems from wireline networks as they did in the past. They are controlled as part of more general network management functions by a signaling mechanism within and among networks.

(4) *Intelligent agents* are software programs that could deal with the clearinghouse and search the spectrum for the best value.

(5) *Digital communications* have made huge strides and reached broadcasting, too. Digitalization facilitates signal compression. The extension to packet-or cell-based technology has long been used in packet radio. Mobile code division multiple access (CDMA) is a move in that direction.

(6) *Spread spectrum* technology is one way to frequency-changing and frequency-sharing by multiple users. Spread spectrum cordless phones are commercially available. There has also been much progress in the development of dynamic channel assignment and distributed control processes for wireless LANs and wireless PBX.

(7) *Token ring LANs* have established the concept of assigning access to a shared transmission facility to those holding an electronic token.

(8) *Encryption* and digital cash have made enormous progress. They could be used for the access codes that permit transmission to be part of a network.

The challenge to technologists and entrepreneurs is to put the various elements together.

On the regulatory front, some steps in the direction of openness were taken by the FCC in 1985 in its Part 15 rules, which increased the unlicensed use of spectrum bands used by industrial, scientific, and medical (ISM) low-power applications (such as garage openers) to the higher transmissions strength of one Watt, provided that spread spectrum technology was used. This led to a very successful expansion of usage, e.g. for wireless LANs and bar-code readers.

The concept was expanded in 1994 to unlicensed personal communications (U-PCS), open to all users of asynchronous data and isochronous time-division duplex voice. The dynamic real-time coordination of use is accomplished by users following a 'spectrum etiquette' in real time, based on rules agreed upon by the industry and approved by the FCC. They are, basically, 'listen-before-transmit' on a channel, 'don't talk too long without listening again', and 'don't talk too loudly', i.e. limitation on transmission power. A potential user seeking transmission, when encountering a 'busy' channel, either switches to another or awaits his turn. This etiquette is embedded in the device itself. The etiquette does not require inter-operability between the various devices or exchange of information among them.

[29]The cost per million of instructions per second (MIPS) for both digital signal processor and control processor units has dropped below $10 per MIPS, and drops by half every few years. The absolute number of operations per second per chip is in the hundreds of millions and sufficient now with digital mobile radio applications (*Ibid*; Baines, R., 'The DSP bottleneck' *IEEE Communications Magazine*, May 1995, 46–54).

Coordination, including the relocation of existing users and definition of channels and geographical regions, is administered by a private non-profit company, UTAM, Inc., owned by equipment manufacturers and supported by them in proportion to their U-PCS equipment sales. UTAM is basically a cooperative.

The next steps in this evolution were two petitions to the FCC in 1995. The first, by WIN Forum, was for a short-to medium-range high-speed Shared Unlicensed Personal Radio Network (SUPERNet). The second petition, by Apple Computer, was for a National Information Infrastructure (NII) Band, with a range of up to 10 miles. Both systems propose a built-in etiquette. The petitions for spectrum were approved in January 1997, and 300 MHz were allocated, with limits on broadcast power to limit interference.

The main weakness of the unlicensed access approach in its present stage is that it deals with scarcity and congestion by a technological 'etiquette,' which cannot ensure real-time access if demand is high. The best-working etiquette for the allocation of a scarce resource in our society is a market-clearing price. Without it one may re-enact the rise and fall of citizens band radio. CB radio is the poor man's open access. CD radios are unlicensed, and their usage was tremendous, even though much of it proved to be a fad. The weakness of CB radio was the absence of congestion prices and of commercial incentives for content provision.

More government intrusion?

Auction advocates tend to stress the rapidity of its allocation, in contrast to the messiness of market trading. But this focuses on the short term. It is true that efficient resource allocations are accelerated by auctions. But soon thereafter, given the dynamics of markets and technology, an aftermarket must take over anyway. The key to spectrum efficiency is therefore a smooth aftermarket more than the initial allocation mechanism.[30] And here, auction-based allocation system will turn out to be only the beginning of problems if the market structure in a service as in spectrum ownership becomes oligopolistic due to potential oligopolists' ability to bid higher. Therefore, such a system may well end up requiring more government intervention than presently hoped for in order to maintain market competition. This is certainly a lesser possibility under a system of continuous open entry which makes it hard to sustain oligopolistic prices. In such a system, the government's role is that of providing an initial endowment (the same function as in an auction), and assuring the right and need for each user to clear access through a clearinghouse. It is true that government could interfere in the clearinghouses, but selling full property rights in spectrum does not eliminate opportunities for interference either, just as land use is often heavily regulated even if fully owned. Establishing multiple clearinghouses, each for a different spectrum band and potentially competing with each other as different stock exchanges do, reduces the need for supervision. To argue that it is 'less government' for government to appropriate billions of dollars by auction is to imagine full economic freedom based on full ownership. But this would be based on optimism, not on history, nor on law. A more plausible scenario is that the government will first auction off spectrum, and then add regulatory restrictions on it over time.[31]

[30]DeVany, A S Implementing a market-based spectrum policy, conference on the law and economics of property rights to radio spectrum, Institute of Governmental Affairs, University of California, Davis (Marconi Conference Center, Tomales Bay, California, July 1996).

[31]To levy restrictions up-front would lower auction revenues and would make the government pay for the obligation it imposes.

Is ownership important?

Without secure long-term tenure there may be less investment. In the exploitation of frequencies, on the other hand, greater competition also spurs innovation and investment. One needs to balance certainty with contestability. Uncertainty exists in every business, and no firm can control every input. Spectrum is no different in that respect from a gas station that cannot be certain of the price of its vital input wholesale gasoline, or of a bakery that needs to buy flour at varying prices. Similarly, employers do not 'own' their employees and are not 'dispossessed' by their departure to firms offering higher salaries. But when it comes to spectrum, much of private industry is so used to the concept of control (whether by ownership or licence) that it finds it hard to conceive of regularly buying spectrum access like another input. Of course, for some firms certainty will be considered necessary, and for that purpose future markets for capacity will evolve.

Couching the discussion in the terms of property rights is analytically not especially helpful. Even the old licence system was one of property rights, regardless of the 1934 Communications Act's declaration that it did not establish ownership right (47U.S.C. 301). It is similarly argued that the auctions are not for full ownership and only for a long-term usage rights. But this is a legal distinction without a real difference. The strong expectation is that the lease will be almost automatically renewed, just as it has been for TV broadcast licences, where of more than 10 000 renewals between 1982–1989, less than 50 were challenged and fewer than a dozen were not renewed, usually because of some malfeasance. A postcard suffices to renew a licence. In cable TV the non-renewal of franchises is similarly rare. For all practical purposes, the auctions are for permanent occupancy, though the slight uncertainty will lower the prices a bit.

As Richard Posner observes:

> In economic, though not in formal legal terms, then, there are property rights in broadcast frequencies... once obtained the right is transferable.... and it is for all practical purposes perpetual. The right-holder is subject to various regulatory constraints, but less so than a public utility, the principal assets of which are private property in the formal legal sense.[32]

Could an auction winner administer an open system itself?

An appealing alternative route to open access would be for private parties to own and administer bands. This would require a competitive spectrum market because if a firm has market power in spectrum it would charge spectrum users monopsony prices, price-discriminate, and appropriate the efficiencies of rivals. It would be like having the old AT&T auction off the right to compete against it. Under such a system, MCI would not have emerged. In a world with many wholesale spectrum band managers controlling a lot of spectrum to make resale transactions with many resale users practical, a substantial openness would indeed be achieved. This could be an ideal system. But such a world is unlikely. For meaningful access to be provided by a wholesaler, it would need to control a significant band, which is likely to be unaffordable by any but the largest of telecommunications consortia. Imagine a firm buying half the VHF TV broadcast band for resale to broadcasters. As Robert Crandall points

[32]Just calling some rights property does not make them the base of an economic efficiency. Under feudalism and absolutism, many rights and privileges were property and for sale, such as military commands, and titles of nobility. People could sell themselves into bondage, or buy their freedom. Yet by no stretch could one describe these systems as efficient. It all depends on the context, which in economics means on the market structure. A property rights system that has a built-in tendency to oligopoly, for example, would not be (Posner, R A *Economic Analysis of Law* (2nd ed.) Little, Brown and Co, Boston, MA, 1977, p 33).

out,[33] on the New Zealand experience with spectrums of management rights (the only concrete example to date for an effort to institute a resale system), based on recent auctions, a single nationwide Gigahertz would be worth in the US about $300 billion, 12 times the value of the giant RJR Nabisco leveraged buy-out. "It is far from clear who would be able to 'bid' for such a franchise if the US government were to offer it as a management right at an auction." Milton Mueller similarly finds that in New Zealand, "spectrum management rights can be acquired since 1990, but they have not been resold to others".[34] Only two local bidders showed up for the management auction in New Zealand, the previous monopolists in telecommunications and broadcasting, respectively. It is hard to imagine that their motivation is to encourage usage by competitors.

Alternatively, spectrum slices for wholesalers could be drawn narrowly, but then the spectrum agility of users access moving around the spectrum would be curtailed.

Advocates of resale markets need to explain the empirical fact that there was never any meaningful resale of non-advertising time-slots for spectrum access by broadcasters, even in multi-station markets, (or by cable companies for their bandwidth). Partly this was due to FCC restrictions, but there did not seem to be major complaints against these rules, and one suspects that few TV stations would become time brokers or common carriers even if they could, as they now partly do. In telecommunications, to take another example, resale exists primarily due to legal common carriage obligations, and has been strenuously resisted by incumbents everywhere. The basic problem is the resistance to provide a competitor with a vital input at a price that permits entry.[35]

Some resale is taking place in satellite transmission. Here, the huge hardware and launch costs and the need for government backing in international bodies cause indivisibilities and entry barriers that lead to a limited number of capacity providers reselling transponders (channels) to large and stable tenants. Such a market is moving in the right direction as long as the need of the handful of firms to shield their huge investments does not lead to a significant anti-competitive cooperation. PCS licencees are also able to resell their spectrum. But it appears this will be done primarily by the 'small business' winners of small regional bids (Basic Traffic Areas) who resell to larger nation-wide firms which were excluded from the regional small-business auctions. Thus, resale is taking place upwards to large aggregative firms rather than downwards to multiple users.

Resale is clearly a step towards open access. It should be encouraged. It is likely to exist in some fashion. But it is not likely to generate a widespread openness of access.

Conclusion

The open entry spectrum exchange will not solve every problem of today's auctions. New ones will emerge. Many of these problems may be resolvable once the technologists focus on them, but to do so requires first that we get out of the box of the exclusivity paradigm.

But even if the open access system has some flaws, the constitutional issue must still be answered. Efficiency of resource allocation and lower transaction costs do not overcome the protection of fundamental rights of which free (electronic) speech is one. If an open-access system is less

[33]Crandall, R W *New Zealand Spectrum Policy: A Model for the United States?*, Conference on the Law and Economics of Property Rights to Radio Spectrum, Institute of Governmental Affairs, University of California, Davis (Marconi Conference Center, Tomales Bay, California, July 1996).

[34]Mueller M. New Zealand's revolution in spectrum management. *Information Economics and Policy,* **5:** 1993; 159–177

[35]Noam, E *Interconnecting the Network of Networks* forthcoming, 1997.

restrictive than an auction/ownership model without causing spectrum chaos, the granting of exclusive speech rights may not pass the test of constitutionality. Even some inefficiencies and transaction costs cannot defeat constitutional rights.

What are some of the policy implications? The conclusion is not to advocate stopping auctions, since in the present state of technology they are still usually the better solution. But it means to limit the duration of auctioned licenses, in order to preserve future flexibility for other approaches.

Secondly, resale and spectrum use flexibility should be encouraged to facilitate resale markets. Licence holders should be able, in most cases, to slice up the spectrum and resell and sublet them to others for various applications.

Thirdly, experimentation and innovation should be encouraged. Why not, for example, expand the unlicensed spectrum concept and dedicate a few bands to the open-access, access-price model? Its practicality is a matter of technical evolution and market realities. Better to approach spectrum use in a pragmatic and searching fashion than with an ideological mind set that equates the free market with one and only one particular technique. We should be ready to take the next step. The tremendous success of the Internet should lead us to seek its openness in spectrum use, too. The Internet, with its multiple route system, is an example for an open-access model in the wireline environment. Open does not mean free or non-profit. Here, too, congestion charges are being considered;[36] similarly for computing.

It took Leo Herzel and Ronald Coase almost 50 years to see their auction paradigm implemented. Similarly, the proposed open access paradigm is not likely to be accepted anytime soon. But its time will surely come, and fully bring the invisible hand to the invisible resource. Resources, real-time transaction markets for usage are being discussed.

[36]Mackie-Mason and Varian *op cit* Ref 14.