CIDRD Working Group
Internet Draft

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Suggestions for Market-Based Allocation of IP Address Blocks
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Status of this Memo

ABSTRACT

Market-based allocation of the existing 32-bit address space will offer several advantages as unallocated space becomes scarce. Most importantly, addresses will be allocated to those who value them most. In addition, address allocations will adjust more quickly to changes in network topology or utilization efficiency. A registry will still be required, much like a registry of deeds for real estate, but the registry would no longer make allocation decisions.

1. ADDRESS ALLOCATION TODAY

The 32-bit address space used in IPV4 has been and continues to be allocated through an administrative process. Internet Service Providers and other organizations submit applications to the InterNIC or a delegated registry such as RIPE. The main criterion for accepting or rejecting an application is efficient utilization of the requested block [1]. The registries take great care not to assign the same address to two different organizations. The Internet Service Providers may in turn delegate number assignments to customers. Occasionally, ISPs go out of business or organizations stop using certain address blocks and voluntarily return them to a registry for reassignment.

Assignees do not pay for the numbers they receive. The InterNIC itself is subsidized by the NSF. This panel is supposed to propose methods of making the InterNIC self-supporting. I propose to remove one of the functions of the InterNIC registration services to a free market, leaving a much restricted function that will be less costly to run.

2. WHAT'S WRONG?

One weakness of the existing procedure is that there are no incentives to return address blocks for reassignment to other organizations that may be able to make better use of them. Over time, an organization's needs may change and the address block may become underutilized. The network topology may also change, so that routing would be far more efficient if an address block were reassigned. A convincing argument for the need to adjust address allocations over time appears in [2].

A second weakness will surface as the address space becomes scarce. Approximately half of the addresses have been assigned so far, with the exact amount depending on one's definition of assignment (ftp://ds.internic.net/netinfo/ip_network_allocations.95Nov). Extrapolations from current trends indicate that the space will last until sometime in the next decade (ref. Tony Li's graphs.) As the unassigned space becomes scarcer, the evaluation criteria for new requests are likely to become stricter. The registries will come under increasing pressures from commercial interests, political lobbying groups, and governments. Caving in to these pressures will result in sub-optimal allocations while resisting them may be a Herculean task. Running the registries in those circumstances will be neither cheap nor fun, though it may be profitable if corruption creeps into the system.

3. POTENTIAL SOLUTIONS

One obvious way out of this impending predicament is to alleviate the scarcity, and several technical approaches are in the works. First, CIDR permits registries to tailor the size of an allocation more closely to the number of hosts that will be connected. Prior to CIDR, organizations that needed more than a single class C were routinely allocated an entire class B. Now, an organization can be assigned four class Cs that form a CIDR /22 for routing purposes. Second, some organizations are using designated IP addresses that are not globally unique, so that they do not need to request a globally unique allocation for all their internal computers [3]. Finally, IPV6 will introduce longer addresses, yielding a much larger address space [4]. Still, the prospect of IPV4 address scarcity is quite real, as indicated by the registries ongoing policies of conserving space for potential future requests.

If scarcity cannot be eliminated, allocation decisions should be moved out of the political realm and into the economic realm, which can handle scarcity more gracefully. If we want to maximize social utility, addresses should be assigned to those who derive the most value from them. Some organizations will value addresses more than others and organizations will value particular address blocks differently, due to routing considerations and due to the costs of renumbering away from addresses currently in use.

4. TRANSFERABLE OWNERSHIP

No system of central planning will be able to take into account all the local variations necessary to optimally allocate (and reallocate) addresses. Instead, we should empower local decision making. The Internet community has already taken one step in that direction, by permitting ISPs to delegate numbers that have been assigned to them. We should continue along that path by allowing and encouraging ISPs to exchange entire large blocks with each other.

The simplest method is to invest ISPs and other organizations with a limited set of property rights over addresses. In particular, two rights would come with ownership of an address:

1. Exclusive use. No one else is permitted to advertise that address for routing purposes on the public Internet.

2. Right of transfer. At the organization's discretion, it can transfer the first right to another organization, in return for whatever compensation, including monetary compensation, that it is able to negotiate. Organizations may also temporarily transfer rights, in the form of a lease [2].

An Internet-wide registry of deeds would still be required, to resolve ownership disputes. This would be a slightly different function than that served by today's InterNIC. The registry would not serve any allocation function: it would not review applications and assign blocks. The registry would merely record each transfer of property rights. This registry should be less expensive to run than the existing InterNIC registration service, and could be accomplished purely by computer. It may also be possible to distribute this service, permitting multiple registries of deeds to share a common database. These registries could then be offered on a pay-for-service basis, and compete with each other on price or quality of service.

5. ROUTING IMPLICATIONS

Note that there is no "right to routing" that comes with address ownership. Others are prevented from using the address for routing on the public Internet, but the address owner may need to make

separate arrangements to ensure that traffic destined for that address is routed properly to a machine that it chooses. In particular, some ISPs may only route for large aggregate address blocks, so that ownership of a single IP address may not be very valuable. It may be more valuable to own a single /18 than to own 64 **separate /24 addresses because almost everyone is currently** willing to include a /18 in router tables. That means that an organization can switch ISPs and still continue to use the same /18 address block.

The idea of charging for router table entries or BGP traffic has been floating around the IETF community for a while and is now receiving serious consideration in the cidr working group. Such charging mechanisms could mesh well with this proposal. Given current technologies, we have to make tradeoffs among the worthy goals of small router tables, route optimization, efficient address space utilization, and address portability. Since the costs of renumbering or of suboptimal routes vary between organizations, separate charges for addresses and for routing will provide incentives for organizations to make appropriate tradeoffs. In fact, it may be that neither charging mechanism will work well without the other: mixing market-based decisions with administrative ones may lead to sub-optimal decisions in both address allocation and routing.

One effect of routing charges will be to create a premium price for large address blocks, which has a couple of implications. First, most of the market participants are likely to be large organizations and ISPs. Most small customers will continue to purchase a service from ISPs that combines lease of addresses with routing privileges. Second, there are likely to be ISPs (or even speculators) who purchase specific blocks to complete larger CIDR blocks. This is analogous to lot assembly for large building construction. The assembly service is valuable to the Internet as a whole, because it simplifies routing, and the premium price for larger blocks will offer appropriate incentives to those who perform it.

6. INITIAL ALLOCATION

If we are to switch to a system of transferable property rights, the question naturally arises of who should own the addresses initially. Many would argue that all the addresses are currently owned by the community as a whole, and merely loaned to their current assignees. Others would argue that the current assignees should be granted ownership. In any case, there are unallocated and unassigned addresses and some organization would need to be given initial ownership of them.

Decisions about who initially gets property rights to addresses will impact wealth distribution, especially if addresses become

scarce and trade at high prices. Those who obtain large initial property rights may enjoy a windfall. Fortunately, however, the initial allocation should have little impact on whether an optimal allocation is achieved. In a famous paper, Coase pointed out that as long as exchanges are easily arranged, property will eventually end up in the hands of those who value it most, regardless of who owns it initially [5]. If the government of Burundi receives a large initial allocation but has few computers it wishes to attach to the Internet, it should sell or lease the addresses to someone who can make better use of them. Fairness and social justice, then, should be the primary criteria for deciding initial allocation of property rights.

As the least disruptive option, I suggest that property rights be given to current assignees. It would be up to ISPs to negotiate with their customers over ownership of the addresses they have reassigned in the past or reassign in the future. IANA or other bodies may choose to retain ownership of some blocks. The remaining unassigned blocks would be auctioned off, just as the U.S. FCC recently auctioned off spectrum for wireless communication. That auction should be designed carefully, but I do not address its design in this paper. Then there is the problem of who gets the proceeds from the auction. Some might be retained by a body such as the Internet Society or the IETF for future use that benefits the entire network. If the proceeds are very large, it may be appropriate to donate them to some international organization.

7. ELECTRONIC MARKET ADVANTAGES

To encourage transfers of ownership whenever such transfers are mutually beneficial, it may be desirable to form new market-making institutions. The market will enable interested buyers and sellers to find each other. It can also help in what economists call "price discovery," the identification of a common market price for similar goods.

Price discovery is useful for two reasons. First, for those in the market, a well known "going price" avoids the need for bilateral negotiations. A well-known theorem in economics [6] argues that, when neither buyer or seller is sure how much an item is worth to the other party, there is no very good price setting mechanism. Either the buyer will bid lower than his true value or the seller will demand more than her true value, and usually both. Not only is much energy wasted, but skillful negotiators will sometimes miss a mutually beneficial exchange because they are jockeying to get the best price.

Price discovery is also useful for those not in the market. A well-known "going price" permits other organizations to decide whether or not to enter the market, and to plan for the future. In

the case of IP address blocks, it will provide useful signals about how much should be invested in technologies that alleviate scarcity. For example, if IP address blocks are selling for a high price, there will be an incentive for the creation of renumbering tools, so that organizations that are underutilizing their address blocks will be able to consolidate cheaply and sell off some of their blocks. High address prices may also hasten the deployment of IPV6.

It is possible to introduce price-based incentives into the administrative allocation process without turning completely to market based allocation. Registries could lease address blocks for a fee, as suggested in [7]. Such an approach, however, misses the opportunity for price discovery. Unless the registries conduct auctions for leases, they will not know the optimal prices to set and hence the self-selections that ISPs make based on those prices will not lead to an optimal allocation.

8. MARKET DESIGN GOALS

The market-maker that facilitates exchanges can be a private party not affiliated with the InterNIC. There can be competition among market-makers, based on the cost of transactions, speed, and other factors. The primary goal of anyone designing such a market should be facilitate all and only those exchanges that are mutually beneficial.

An area of theoretical economics devoted to designing such markets is called "mechanism design." A mechanism is a set of rules for submitting bids and offers and for resolving those bids to match buyers and sellers and determine prices. If the buyers honestly reveal the maximum price they are willing to pay and the sellers honestly reveal the minimum price they will accept, it is straightforward to arrange an optimal set of exchanges. The problem is that the rules for determining prices may give buyers and sellers incentives to make bids that do not reflect their true values.

One well-known mechanism that does encourage honest revelation is called a second-price auction. It can be used when there are many buyers, but just one seller selling a single product. Each buyer seals a bid in an envelope. All bids are opened simultaneously. The highest bidder gets the product, but pays a price equal to the second highest bid. The amount of your bid determines whether you will win the auction, but has no impact on the price you'll pay, so there is no point in bidding anything other than your true value.

The market for IP addresses may be slightly more complicated. There are many possible address block sizes for sale and there are complementarities among blocks. As suggested above, a set of 16

contiguous class C addresses that can be assembled into a single /20 CIDR block will likely sell for more than 16 scattered class C addresses. Thus, the mechanism choice for an IP address market will be an interesting research problem for economists and network engineers to solve together.

9. POTENTIAL MARKET FAILURES

The arguments above have assumed a somewhat idealized situation of a perfectly functioning market. Market participants are knowledgeable, transaction costs are negligible, there is no abuse of market power, there are no externalities, and equity concerns can be separated from efficiency concerns. In reality, these assumptions may be violated to a greater or lesser extent.

First, if market participants are not knowledgeable, they may make suboptimal decisions for themselves. The government of Burundi may sell its initial allocation of addresses at a low price, not realizing that in a few years it will want those addresses. Organizations that do not understand the importance of route aggregation may buy small address blocks on the open market and then find that ISPs will not route traffic to those addresses. In such situations, the registries may be better at determining the value of address blocks to individual organizations than those organizations are. If, however, the market is mostly for trading among large organizations and ISPs, it is reasonable to expect them to understand their particular circumstances better than any central administrative authority will.

Second, if transaction costs are high, such as the cost of negotiating a price or registering a transfer with the registry of deeds, suboptimal allocations are likely to continue. There is no reason, however, for these costs to be high. Note that renumbering costs should not be viewed as transaction costs: if an organization uses an address block sparsely but has high renumbering costs, its actual value for the address block may be quite high, and it may be optimal for that organization to continue using the addresses sparsely.

Third, there may be a concentration of market power. Geoff Huston's analysis of address allocation is similar to that presented here, but he views market-based exchange as something to be avoided, because ISPs might act as an oligopoly to erect barriers to entry for newcomers [7]. As the number of competitors increases, however, they are more likely to compete than to collude. A related problem is the possibility of speculators acquiring large numbers of addresses and keeping them off the market in an attempt to create artificial scarcity that drives up prices. Cornering the market in this way is a difficult strategy to implement, but it is a real danger to the community. The market may need to be governed by securities exchange laws such as those

that govern the U.S. securities and commodities markets. Alternatively, since "ownership" exists only by mutual agreement of other parties, perhaps the IANA or the ISPs would retain the right to confiscate and reallocate addresses that are withheld from the market in an attempt to drive up prices artificially.

Fourth, there are wealth distribution questions. Suppose that a university in Thailand is willing to spend $100 for a block of addresses, but a large company is willing to spend $500 for those addresses, to be used for profit-making purposes. It is tempting to say that willingness-to-pay is a poor measure of which use is more valuable, especially if the university has less wealth to spend. Questions of wealth distribution and equity, however, should not be confused with allocative efficiency. For example, suppose the Thai university acquires the addresses for $100. If permitted to do so, it will resell them for $500 spend the money on something it thinks is more valuable. This amounts to a $400 wealth transfer to the university, but has no effect on the allocation of addresses. If resale is not permitted, on the other hand, the university keeps the addresses, but there is a deadweight loss: both the university and the potential purchaser would be better off if the resale were permitted.

Finally, there may be positive externalities that individuals will not take into account when allocating through the market. Each new addition to the Internet creates a benefit for everyone who is already connected, because they have someone else to share information with. This argument is often used to justify subsidy of telephone service for high-cost and low-income subscribers, in order to generate universal or near-universal service. Unlike the wealth distribution argument, this one may justify subsidizing addresses for the Thai University: connecting a university from an under-represented region may create larger externalities for the rest of the Internet community than would connection of another commercial organization. A separate fund may be needed to subsidize connections from less represented regions, so that we can all benefit from worldwide connectivity. This fund might be modeled on the one proposed by Eli Noam for funding universal telephone service in a competitive environment [8]. Money collected from the initial auction of addresses might also be used for this purpose.

10. SUMMARY

The essence of this proposal is to make address assignments transferable and condone the practice of money changing hands as part of such transfers. The best way to make use of an address block depends on how valuable it is to attach various devices to the Internet, on routing considerations, and on the costs of renumbering. By devolving authority to those who are intimately acquainted with these costs and benefits, better decisions can be

made. By introducing money into the mix, parties will have the incentives to make those better decisions. This proposal would complement a proposal to introduce incentives for route aggregation. Rather than fighting the profit motive, the Internet community should harness it to give individuals and organizations incentives to act in ways that improve resource use.

Taking allocation decisions out of the hands of the administrative body will reduce its workload, and avoid many of the headaches that would arise if administrative allocation procedures continue into an era of scarcity. The registration function would be reduced to simply keeping accurate records of the current ownership of address blocks.

One new coordinating function will be required, that of market maker. This function need not be officially sanctioned, however, and several organizations can provide competitive services. An important design goal for the market makers is to set up an environment in which honest revelation is the best strategy, so that all the profitable exchanges can be arranged.

11. REFERENCES

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12. SECURITY CONSIDERATIONS

Security issues are not discussed in this memo.

13. ACKNOWLEDGMENTS

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