Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C.

In the Matter of Modification of Parts 2 and 15 of the Commission's Rules for Unlicensed Devices and Equipment Approval	ET Docket No. 03-201

REPLY COMMENTS OF MICROSOFT CORPORATION

In its initial comments in this proceeding[1] Microsoft proposed three simple sharing rules to address how unlicensed devices should behave to promote greater coexistence and spectrum efficiency in new unlicensed bands. These rules would: prohibit devices with an information rate of zero from occupying a channel; require devices to monitor a channel before and during transmission to ensure that a specific aggregate interference threshold is not exceeded; and require devices to incorporate reasonable transmitter power control. [2]

The application of these three rules will allow spectrum in new unlicensed bands to be used more intensively with a higher quality of service than is possible in the current unlicensed bands, without limiting innovation. Nevertheless, as expected, some parties to this proceeding expressed concerns about the adoption by the Commission of any sharing rules for any unlicensed bands.

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[1] *Modification of Parts 2 and 15 of the Commission's Rules for Unlicensed Devices and Equipment Approval*, Notice of Proposed Rulemaking, ET Dkt. No. 03-201 (rel. Sept. 17, 2003) ("NPRM").

[2] *See* Comments of Microsoft Corporation ("Microsoft Comments") at 5-6.

The assumption in many of these comments is that the Commission can choose between sharing rules and **no** rules about how spectrum is to be shared. That, of course, is wrong. The existing Part 15 rules constitute a detailed (and often amended) regulatory scheme that creates incentives and disincentives to build certain kinds of radios. It creates an incentive, for example, to build a radio that uses as much power as possible and as much bandwidth as possible. The three additional sharing rules proposed by Microsoft would, in new bands, alter the incentive structure. Simulations run by Microsoft, and presented below, establish that these proposed sharing rules would permit more intensive use of the spectrum for broadband applications. The real question that faces the Commission is not whether there should be sharing rules or no sharing rules – but whether this clear public interest benefit of the rules proposed by Microsoft is worth whatever costs they would impose. While Microsoft believes the answer to this question is obvious, it is nevertheless an important question worthy of serious discussion.

DISCUSSION

While Microsoft strongly supports the creation and application of spectrum sharing rules to new unlicensed bands, it recognizes that some commenters were skeptical of what the Commission termed "spectrum etiquette" rules. Many commenters were concerned about the application of sharing rules to existing unlicensed bands.[3] Not surprisingly, these commenters were concerned about the fate of existing devices in bands that have no spectrum sharing rules. Microsoft thinks that many of these concerns are reasonable, and believes that sharing rules should be directed to new unlicensed bands as they become available.

[3] *See for example* Pegasus comments at page 2; Alvarion comments at 14; Globalspan Virata, Inc. comments at 15.

Other commenters – having participated in the evolutionary success of the 2.4 GHz and 5 GHz bands – are concerned about overly prescriptive technical regulations that could cause technology developers to abandon frequency bands where such regulations apply in favor of bands with more liberal technical rules. When these parties think of sharing rules, they understandably think of – and fear – spectrum etiquette rules like those applied to unlicensed PCS. Again, Microsoft does not dismiss such concerns. The unlicensed PCS spectrum etiquette rules were, in fact, prescriptive.[4] But this need not be so, and the rules proposed by Microsoft are not prescriptive. They demonstrate that sharing rules can be both non-prescriptive and effective.

Indeed, many commenters seemed to understand that sharing rules, if done well, could contribute to the increasing success of unlicensed broadband services. They indicated a clear willingness to work together either in industry groups or with the Commission to develop rules *in new unlicensed bands* for performance requirements along the lines of what was recently adopted for the 5 GHz unlicensed bands.[5] With these commenters, Microsoft agrees fully.

I. Microsoft's Proposed "Unlicensed" Sharing Rules Will Not Favor Particular Technologies, Stifle Innovation or Give an Advantage to Particular Users

The welcome proliferation of unlicensed devices used for broadband applications practically screams for easing broadband access in new unlicensed bands by adopting minimal sharing rules.[6] This is because most of the Commission's existing rules were

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[4] Nortel networks (a participant in developing the unlicensed PCS rules) seems to give a fair account of some of the issues associated with those rules that may give parties pause in agreeing to any new sharing rules. *See* Comments of Nortel Networks at 14.

[5] *See for example* Matsushita comments at 8; Information Technology Council comments at 7-8, noting that unlicensed last mile networks will require greater reliability than might be available today.

[6] Microsoft Comments at 3.

developed when lower data rate applications were the norm. If the success of "unlicensed" broadband devices is to continue as they proliferate in new – and particularly – lower bands, general sharing rules should be established and tailored to broadband use.

Some have raised concerns that any sharing rules would give an advantage to particular technologies.[7] Microsoft agrees that the Commission should carefully avoid making technology choices. But the Commission's own recent experience demonstrates that the type of rules Microsoft proposes would not dictate a specific technology implementation, nor limit technical innovation. The general sharing rules Microsoft advocates are simply performance requirements; they are not design specifications.[8] Indeed, in the just completed 5 GHz proceeding, the Commission adopted performance requirements similar to those advocated by Microsoft.[9] These 5 GHz requirements – like those suggested by Microsoft – are implementation agnostic.

Another concern raised by some is that adopting general sharing rules will stifle innovation. In fact, the opposite is likely true. When spread spectrum rules were originally adopted for the 2.4 GHz band, there were those who thought that the Commission's power limits and other technical requirements would render the band useless for any practical commercial use. How wrong they were. Instead, those fairly general rules were a challenge for smart designers who appreciated the increased power

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[7] *See for example* Comments of Intel Corporation ("Intel Comments") at 6.

[8] The exact "numbers" associated with the performance requirements would necessarily be tailored on a case-by-case basis and will depend on frequency band, interference environment and the intended unlicensed use.

[9] *See Revision of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) devices in the 5 GHz band* 18 FCC Rcd. 24484 (2003) ("5 GHz *Report and Order*").

the FCC simultaneously provided unlicensed spread spectrum devices. That challenge was accepted and spurred the creation of the "Wi-Fi" industry we know today. Similarly, the sharing rules envisioned by Microsoft – precisely because they are general – can provide guidance for farming new bands, spurring new "industries" and providing for widespread economical broadband access.

Another concern raised is that sharing rules will lead to a "first user" hogging available spectrum. Intel opined that requiring spectrum monitoring would "encourage the design of devices that 'squat' on frequencies foreclosing future unlicensed users."[10] Microsoft shares Intel's concern about first users "hogging" spectrum in a particular area. But as the example provided in Microsoft's initial comments shows,[11] benign neglect is not the answer. The best way to prevent first users from moving into an area and keeping the spectrum to themselves is the kind of "non-greedy occupancy" sharing rule Microsoft proposed. Further, a spectrum monitoring performance requirement has nothing to do with channel occupancy. In Microsoft's construction, spectrum use is monitored at the receiver before an active transmitting link is initiated. Once a link is established and

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[10] *See* Intel Comments at 6-7. In addition, Intel misstates in its comments the relative status and rights of unlicensed services which lead it to several mistaken conclusions. Specifically, unlicensed operation is not a secondary use as Intel infers. *First in time secondary users have rights versus other secondary users,* but unlicensed users have no rights versus other unlicensed users. This is another reason why general performance requirements will result in more equitable spectrum use among unlicensed users. Nor is "secondary use by unlicensed devices" predicated on negotiated agreement with primary users. The rights of unlicensed users vis-à-vis primary users are clear – the unlicensed users have no rights. This being the case it is impossible – as Intel suggests – to address this "easy" situation rather than to create "technical rules for sharing among co-equal secondary users." Intel also infers that in a given area a "property owner" has control over contending devices thereby avoiding "tragedy of the commons" issues. That too is wrong. While the "property owner" might have control over his or her own devices, that property owner has no control over (or rights to) the airwaves. Today any other unlicensed "property owner" (for example an apartment resident with a common wall) can deploy a devastatingly interfering system without consulting the first "property owner." With no control over airwaves that penetrate walls, it does not matter whether the "property owner" has control over its own devices.

[11] Microsoft Comments at 4-5, describing the "Wi-Fi Hog."

communication is completed, the link is relinquished and the previously occupied spectrum is available for others to use. Thus, Microsoft's three simple rules cannot favor one unlicensed user over another – the "first user" having relinquished spectrum has gained absolutely zero rights over the "n-th" user in that area.

II. SHARING RULES ARE NOT LIKELY TO INCREASE COSTS SIGNIFICANTLY

Some commenters raised a concern that sharing rules would raise the cost of equipment, and that this added cost would outweigh the benefits.[12] But the rules Microsoft proposes can be satisfied with existing technologies (though newer technologies may well come along) and, in fact, already apply in part in some bands.[13]

This is not to say, of course, that more sophisticated devices will not cost more than dumb devices. But if sharing rules are applied to new unlicensed spectrum, it is reasonable to assume that new devices will be developed specifically to take advantage of the propagation characteristics of these new bands and new Commission rules. If performance requirements for sharing are known at the outset, the cost of incorporating these functionalities into newly designed devices is likely to be inconsequential. On the other hand, the benefits of sharing rules for spectrum efficiency and reliability are likely to be enormous. As the Commission knows, given the costs imposed on others by cheap radios, the cheapest radio to make is not necessarily the least costly radio to operate.

III. MINIMALIST SHARING RULES HAVE DEMONSTRABLE BENEFITS

The Commission has an opportunity to create a new success story in new unlicensed bands by adopting minimalist sharing rules for advanced wireless networking

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[12] Motorola comments at 5.

[13] *See* 5 GHz Report and Order. *See also* 47 C.F.R. Section 101.113.

devices. Microsoft's general "three simple rules" scheme can be a catalyst for technological innovation that will lead to "horizontal" sharing arrangements among unlicensed devices in newly identified bands.[14]

Microsoft's three basic "unlicensed sharing rules" are: [15]

- Rule I: Non-Greedy Occupancy
- Rule II: Dynamic Channel Select
- Rule III: Dynamic Power Select.

To assess the potential impact of these rules, Microsoft has run simulations to evaluate how effective they might be in limiting interference among unlicensed devices.[16] For its simulations, Microsoft assumed an Orthogonal Frequency Division Multiplex (OFDM) modem with 100 mW maximum transmit power, an omnidirectional antenna, adaptive data rates from 18 Mbps down to 2 Mbps and a 6 MHz channel. In the simulation, Microsoft varies operational modes[17] and conditions to test its three rules.

Rule I: non-greedy occupancy. This rule requires devices to observe "non-greedy" occupancy. A "greedy" device is defined as one that transmits continuously on a channel whether there is data to send or not. Rule I would prohibit devices with information rate 0 (no data to send) from occupying a channel.[18]

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[14] In its Comments Microsoft discusses "vertical" versus "horizontal" sharing. See Microsoft Comments at 3.

[15] Microsoft Comments at 5-6.

[16] See Attachment A.

[17] For example, data rate and receiver sensitivity and indoor versus outdoor operational conditions. *See* Attachment A at 1-2.

[18] Microsoft comments at 5.

To identify the impact of this general rule, a "greedy" node[19] must be inserted into the modeled environment to determine its effect on other devices. Specific details of this simulation are provided in the attachment, but after 20,000 trials[20] the result is that one "greedy" node within 100 randomly placed nodes would block an average of four nodes in the outdoor case and twenty-four nodes in the indoor case from using the channel.

Astonishingly, if 10% of the nodes are "greedy," an average of 33% of the nodes in the outdoor case and 93% in the indoor case would be blocked from using the channel.[21]

Rule II: dynamic channel select. This rule requires devices to refrain from operating on a given channel unless they can do so without causing interference to devices already operating on that channel.[22] This rule requires a device to sense aggregate interference levels at its intended receiver to determine whether its operation would exceed a predetermined (by rule) aggregate Interference Threshold of (I_{th}).[23] To evaluate the effectiveness of Rule II, a simulation was modeled to consider two cases. In the first case, a new link becomes active on a channel without checking interference levels at the intended receiver. In the second case, a device checks the interference level at the intended receiver prior to transmitting on a given channel. For both cases, simulations were run with low levels of background interference (setting one other link

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[19] A "node" is a transceiver.

[20] Trial sets of 10,000 each were conducted for indoor and outdoor scenarios.

[21] Attachment A at 3.

[22] Microsoft comments at 5.

[23] As Microsoft stated in its comments, I_{th} would need to be set for each band, taking into account the likely interference environment as well as the type of unlicensed use anticipated for a given band. *See* Microsoft comments at 6.

active on the channel) and high levels of background interference (setting two links active on the channel). The interference power observed at the intended receiver was calculated to determine the level at which a link is "blocked."[24] The results after 1,000 trials for each case reveal that the channel check rule would cause a significant increase in available "clear" links compared to an environment where channel checks are not performed prior to transmitting.

Rule III: dynamic power select. This rule requires devices to incorporate some amount of dynamic transmit power control ("TPC"). The idea is to lower the overall interference level in a given environment by populating that environment with devices that can adjust their transmit power to the minimum necessary to successfully communicate between transmitting and receiving nodes.

To evaluate Rule III's effectiveness, a number of simulations were run using 100 links randomly positioned in areas of 10, 100 and 1000 meters squared. From one to nine active links in each area were tested. In the first instance, no power control is used; i.e., the active links always operate at an assumed maximum power of 100 mW. In the second case, power control was used to reduce transmit power to the minimum necessary to maintain an 18 Mbps data rate.[25] These simulations were run both for outdoor and indoor environments. The goal of the simulation was to determine the average number of blocked links.

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[24] A link is considered "blocked" if the total interference power prevents the link from being closed (i.e., connected) at the lowest data rate (2 Mbps for these simulations).

[25] In the 700 MHz broadband example, devices are assumed to have a maximum output power of 100 mW and can transmit from 18 Mbps down to 2 Mbps.

Microsoft found that whether outdoors or indoors, with no transmit power control, the average number of blocked links was practically independent of the size of the area considered. However, in smaller areas where the links are shorter, transmit power control yields a significant reduction in the average number of blocked links. In larger areas, transmit power control still yields a reduction in the average number of blocked links. However, because the links between transmit and receive nodes are longer, the effect is not as pronounced.[26] In other words, Rule III is particularly effective where there is a high device deployment density in a relatively small area.

CONCLUSION

Microsoft believes that applying three simple sharing rules to new unlicensed bands will be enormously beneficial as such bands become available for wireless broadband access. The Commission recently adopted similar concepts for the 5 GHz band where – to coexist with other users of 5 GHz frequencies – the Commission required the next generation of U-NII devices to incorporate dynamic frequency selection ("DFS") and transmit power control ("TPC").[27] These coexistence techniques are not unlike incorporating Microsoft's proposed Rules II and III.

Microsoft's proposed sharing rules embody concepts that are not new. In one form or another these concepts are already used by a variety of services in a range of frequency bands. They can be applied to new unlicensed bands in a technology neutral way that will neither stifle innovation nor increase cost. And the benefits of such sharing rules to the growth of wireless broadband can be enormous. Microsoft urges the

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[26] See Attachment A at 3 for specific details on Rule II simulations.

[27] *See* 5 GHz Report and Order at ¶29 and ¶35. *See also* NPRM at ¶43.

Commission to enter an intensive dialogue with industry, and other, stakeholders with the goal of developing and implementing spectrum-sharing rules in new unlicensed bands.

Respectfully submitted,

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Attachment A - Sharing Rules Simulation Study

Simulations were developed to test the effectiveness of Microsoft's proposed Spectrum Sharing Rules for New Unlicensed Bands. A 700-MHz band OFDM[28] modem was modeled with 100 mW maximum transmit power, an omni-directional antenna, and adaptive data rates from 2 to 18 Mbps in a 6-MHz channel. A log-distance propagation model incorporating log-normal fading was used with representative parameters for both outdoor and indoor 700-MHz links.

All three proposed rules are shown to be effective in facilitating spectrum sharing. Rule I, Non-Greedy Occupancy, prevents a small number of greedy nodes from blocking channel access to the majority. Rule II, Channel Select, results in a significant increase in the number of links that can operate on a given channel. Rule III, Power Select, significantly reduces channel blocking in cases where significant power reduction is possible.

Microsoft has proposed three rules for spectrum sharing in new unlicensed bands. They are:

> ***Rule I, Non-Greedy Occupancy****, no user may occupy the channel with information rate 0 (no data to send).*
>
> ***Rule II, Dynamic Channel Select****, a channel is deemed accessible at a node if the aggregate interference power at the intended receiver is less than a predefined interference threshold, I_{TH}.*
>
> ***Rule III, Dynamic Power Select****, for every reduction of transmit range by factor A, the node must reduce transmit power by a minimum of 20 $\log_{10} A$ dB. Practical transmit control should be operational over a dynamic range of 12 dB with step size of 1 dB.*

The simulations are based on nodes and links. Links are pairs of nodes. Each node is a transceiver operating in the 700 MHz band with 6 MHz channels, omni-directional antennas, 100 mW maximum transmit power, 10 dB receiver noise figure, and rate adaptive OFDM modulation. The data rate and corresponding receiver sensitivity are shown in Table 1.

[28] Orthogonal Frequency Division Multiplexing (OFDM) is used in 802.11a and 802.11g equipment as well as many other modern communications systems.

Table 1 – Transceiver Data Rate and Sensitivity

Data Rate	Sensitivity
2 Mbps	-87 dBm
3 Mbps	-86 dBm
4 Mbps	-84 dBm
6 Mbps	-82 dBm
8 Mbps	-79 dBm
12 Mbps	-75 dBm
16 Mbps	-71 dBm
18 Mbps	-70 dBm

A log-distance propagation model incorporating log-normal fading is used.

The path loss (dB) is given by:

$$PL = -27.55 \text{ dB} + 20 \times \log_{10}[F] + n \times \log_{10}[d] + X_\sigma$$

Where: F is the operating frequency (MHz)

n is the path loss exponent

d is the path length (m)

X_σ is a zero-mean log-normal random variable with standard deviation σ that represents the fading (dB).

For outdoor propagation in the 700 MHz band, values of n = 2.4 and σ = 7 dB were used. For indoor propagation, values of n = 3.5 and σ = 12 dB were used.

In the simulation developed to evaluate the effectiveness of Rule I, Non-Greedy Occupancy, 100 nodes were randomly positioned in an N x N area. From 0 to 10 of these nodes were modeled as greedy, i.e. they transmitted continuously on a given channel. The interference power observed on that channel at each of the other nodes was calculated. A node was considered blocked if the total inference to noise power ratio (I/N) at that node exceed 17 dB (i.e. if that node had just been able to operate at 18 Mbps without interference, at 17 dB I/N it would not even be able to operate at the minimum 2 Mbps data rate). Two cases were considered:

- A 10 km x 10 km area with 100 mW transmit power and outdoor propagation.
- A 100 m x 100 m area with1 mW transmit power and indoor propagation.

For each case, 10,000 trials were performed, providing an accuracy of ±1 blocked node.

Figure 1 shows the average number of blocked nodes as a function of the number of greedy nodes for the two cases. Even a single greedy node is seen to block the channel at an average of 4 nodes outdoors and 24 nodes indoors. When 10% of the nodes are greedy, it is seen that the channel is blocked at an average of 41% of the nodes in the outdoor case and 98% in the indoor case.

Figure 2 shows the number of nodes blocked at least 90% of the time as a function of the number of greedy nodes for the two cases. When 10% of the nodes are greedy, it is seen that the channel is blocked at least 90% of the time at 33% of the nodes in the outdoor case and 93% of the nodes in the indoor case. The outdoor case blockage is mitigated by the reduced interference resulting from the larger area. **A small fraction of greedy nodes can block channel access for the majority.**

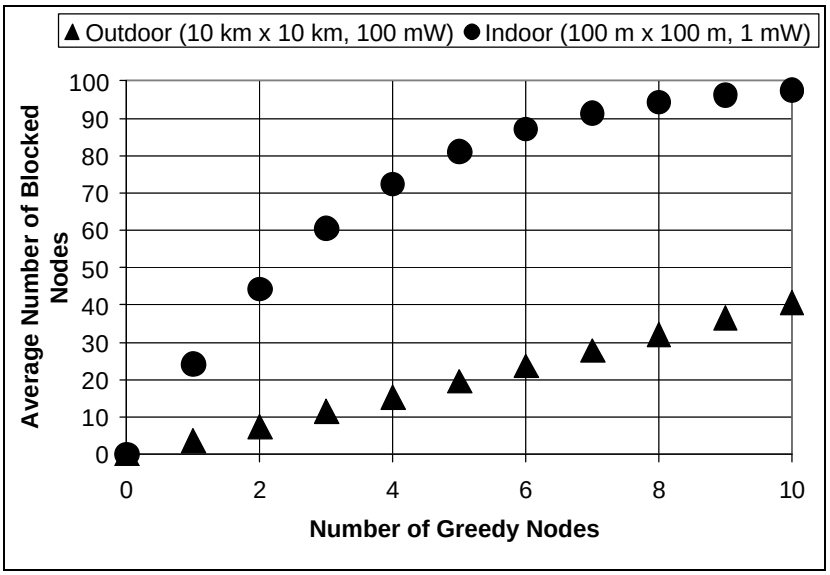

Figure 1 – Average Number of Blocked Nodes

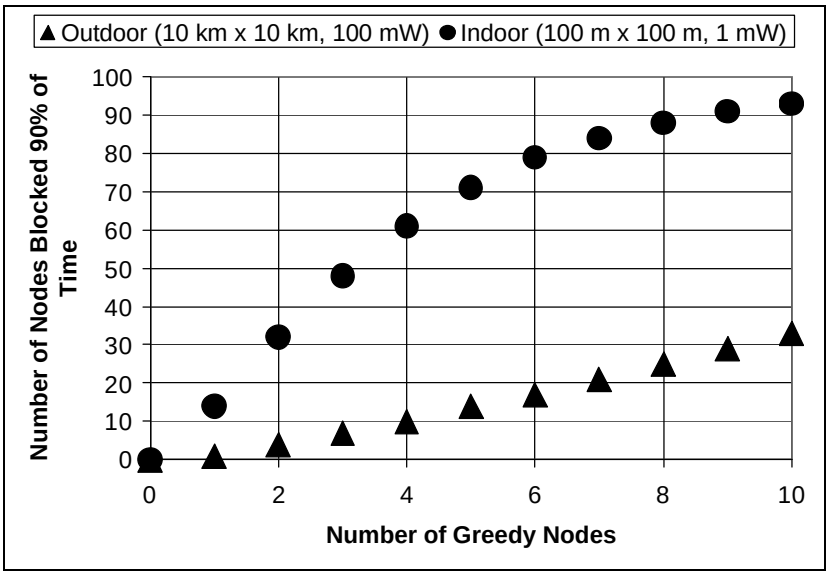

Figure 2 – 90th Percentile Number of Blocked Nodes

In the simulation developed to evaluate the effectiveness of Rule II, Channel Select, 100 links were randomly positioned in a 100 m x 100 m area. Only trials in which all links closed in the absence of interference were considered. Low and high levels of background interference were modeled by setting 1 or 2, respectively, of the links active on a given channel. A new link was modeled as wanting to use that same channel. Two cases were considered:

- No Check – The new link transmits on the channel without any check.
- Channel Check – The new link checks the interference power at its receiving node prior to transmitting on the channel.

The interference power observed at each of the receivers was calculated. A link was considered blocked if the total inference power observed prevented it from closing at the lowest (2 Mbps) data rate.

Figure 3 shows the average number of clear (not blocked) links for four scenarios:

- Outdoor propagation model with low background interference.
- Outdoor propagation with high background interference.
- Indoor propagation with low background interference.
- Indoor propagation with high background interference.

For each scenario, 1,000 trials were performed providing accuracy better than ±1 blocked node.

For each scenario the average number of clear links is shown in Figure 3 with background interference only, with new active link with channel check (Rule II), and with new active link without channel check (no Rule II). A new active link with Rule II is seen to result in a slight reduction in clear links compared to the background case. **A new active link without Rule II is seen to result in a more significant reduction in clear links compared to both the background and the Rule II cases.**

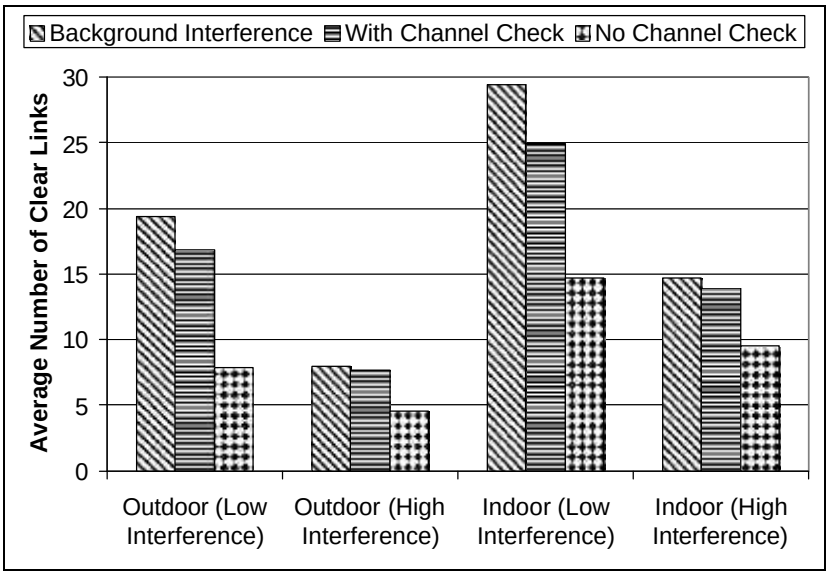

Figure 3 – Average Number of Clear Links

In the simulation developed to evaluate the effectiveness of Rule III, Range & Power Select, 100 links were randomly positioned in a N x N area. Only trials in which all links closed in the absence of interference were considered. Three values of N were modeled, 10 m, 100 m, and 1,000 m. From 1 to 9 of the links were modeled as simultaneously active. Two cases were considered:

- No Power Control – Active links always transmit at full power (100 mW).
- Power Control – Active links operating at max (18 Mbps) data rate reduce transmit power to the minimum required to maintain that rate.

The interference power observed at each of the receivers was calculated. A link was considered blocked if the total interference power observed prevented it from closing at the lowest (2 Mbps) data rate. For each case, 1,000 trials were performed providing an accuracy of ±1 blocked node.

Figure 4 shows the average number of blocked links as a function of the number of active links for each of the three area sizes with and without Rule III, for the outdoor propagation model. The number of links blocked without power control is roughly independent of area size for the sizes considered. **In smaller areas, the active links are shorter and reduction in transmit power due to power control is more significant, resulting in significantly fewer blocked channels.** As the areas get larger, the active links become longer and the transmit power reduction due to power control is less significant, resulting in less of an improvement.

Figure 5 shows results for the indoor propagation model. The results for the 10 m x 10 m and the 100 m x 100 m areas are seen to follow a pattern similar to the outdoor model. In the 1,000 m x 1,000 m area case, interference from one side of the area is severely attenuated by the time it reaches the other side. This limits the number of blocked links in the no power control case and limits the power control improvement.

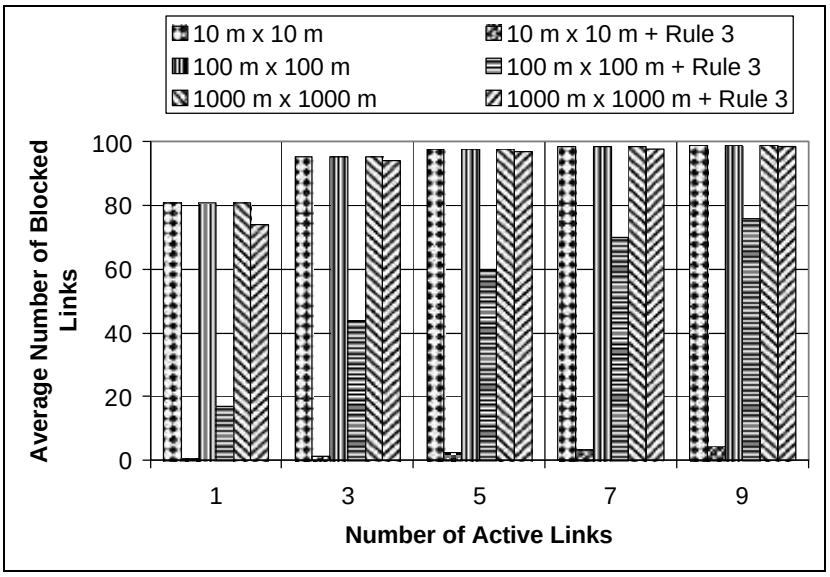

Figure 4 – Average Number of Blocked Links (Outdoor Model)

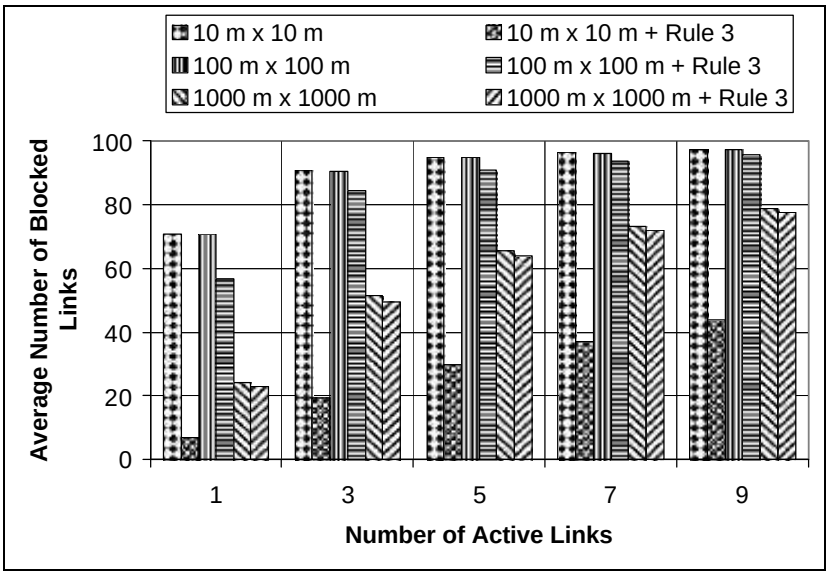

Figure 5 - Average Number of Blocked Links (Indoor Model)

CONCLUSION

Microsoft proposes three minimalist sharing rules for advanced wireless networking devices. The foregoing simulations demonstrate that observing these rules will significantly enhance spectrum sharing potential among unlicensed devices.