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Research Article

EMI-Specific Performance Integrity of OS Migration (Teleportation) Over a Wireless Channel Such as WLAN

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ABSTRACT

The performance aspects of OS migration implemented in a wireless LAN (WLAN) environment is investigated taking into account of underlying physical-layer based constraints due to EMI/RFI implications in the indoor operations. Specifically, the interfering effects of coexisting IEEE 802.11 devices on OS migration are analyzed *via* spectrum spill-over effects and host-to-interferer separation. Basic models are presented thereof and computed results are furnished and discussed. While generic studies, for example, on wireless coexistence between IEEE 802.11 and IEEE 802.15.4 devices prevail, no such efforts *per se* exist on the topic of WLAN supporting OS migration *vis-à-vis* associated EMI/RFI related impairments in the teleportation. As such, this study can be regarded as a novel attempt.

Keywords: EMI/RFI; OS migration; Teleportation; WLAN.

1. Introduction

In the context of modern data-center applications and in clustered computer ambient, use of migration (teleportation) of operating systems (OS) facilitated across distinct physical hosts is considered as an attractive option. It provides separation between hardware and software, ease of fault-management, load-balancing and low-level system maintenance requirements [1].

OS migration (or teleportation) broadly refers to what is known as *virtual machine* (VM) migration. It involves running a virtual machine and moves (teleports) the computational features from one physical machine to another. Such teleportation, however, remains transparent to the guest OS as well as remote clients of the VM. For all participant clients, the VM appears as if it has not changed its location. The only change perceived could be the system slowing down during the migration.

VM moving to a machine also implies possible better performance as a result of envisaging more available resources. The platform of VM (with its hardware and software layers) is illustrated in Fig. 1.

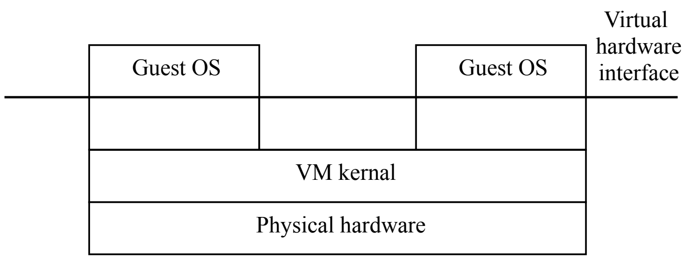

Figure 1: VM platform layers.

2. OS migration in traditional wireline environment: an overview

In implementing VM between physical servers, traditionally wireline strategies are followed. That is, the teleportation at physical-layer level is done in LAN/WAN environment *via* traditional Ethernet connectivity through cables (copper and/or fiber) that support the necessary bandwidth (BW) such as 622 Mbps.

A compelling reason for server virtualization is the underlying ability to move VMs between physical servers. The real advantage of such virtualization is that, it enables production VM to be transferred directly to a physical server, (either to a server within the same data center or to a server in a different data center without any service interruption). In such opera-

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tions implemented on WAN, the associated constraints are as follows: (i) The maximum round-trip latency between source-to-destination should not exceed 5 ms; and, (ii) adequate bandwidth (BW) should be provisioned as decided by OS teleportation applications.

The question of delay (or 5 ms constraint) in WAN transports with signal transmission exercised *via* copper and/or fiber transports, implies that the distance between source and destination can be about 300 miles (500 km). Should the physical link be wireless, this 500 km estimate applies to line-of-sight (LoS) conditions assuming that no delay is sustained at intermediate routers etc. However, the assumptions as above could be very unlikely. The reason is as follows: The delay constraint of 5 ms appears to be set by intervening TCP buffers and synchronous *versus* asynchronous mode prevailing on the storage devices in the OS migration, rather than by the source-destination separation of 500 km [2].

3. Implementing OS migration in wireless ambient

Notwithstanding wireline considerations of WAN in supporting OS migration as above, it is of interest to know the feasible aspects of and over-looming constraints if any in OS teleportation efforts performed indoor *via* WLAN links; and, the scope of present study is to evaluate the performance effectiveness of such OS migration implemented in indoor WLAN operations.

The Part 15 Rules of the FCC allows WLAN operation under ISM band and relevant US prescriptions on the frequency bands are 902-928 MHz, 2.4000-2.4853 GHz and 5.7250-5.8500 GHz with a maximum permissible power level of 500 mW with the option to use spread-spectrum (SS) technique either with direct-sequence SS (DSSS) or frequency-hopping SS (FHSS) strategy [3].

Further, in the context of modern business networking, WLAN has an array of choices that conform to IEEE 802.11a, 802.11b, 802.11g, or 802.11n wireless standards (collectively designated as Wi-Fi technologies [4]). Relevantly, a feasible technology option for "Teleportation-on-WLAN" can be conceived for applications across large indoor premises of business enterprises. Then, an appropriate question that arises is that, to what extent VM operation can be rendered with a required level of performance integrity and reliability *vis-à-vis* the electromagnetic ambient of RF transmissions associated with WLAN.

The question as above is imperative due to well-known concerns about wireless transmission/propagation considerations both indoor and outdoor [5–7]. That is, in practice of WLAN implementations, technologies like Bluetooth^{TM} as well as various other non-(Wi-Fi) technologies may coexist in the same premises (indoor) wherein the OS migration networking *via* WLAN is attempted. Though each of non-(Wi-Fi) technologies is designed for specific networking applications and with specific modulation protocols/methods, there is a possibility of spectral spill-over that could cause electromagnetic (EM)/radio-frequency (RF) interference [5–7] into the WLAN operation affecting the performance of OS migration links being supported .

Suppose OS migration/teleportation is done in WLAN ambient, the following typical performance parameters are implicit:

- BW, for example, 655 MHz with corresponding bps,
- Round-trip delay,
- Signal level.

Inasmuch as, WLAN implementation is done within the indoor local area, the physical source-to-destination distance is small (unlike in WAN). As such, the round-trip delay due to wireless (EM wave) transmission is negligible. However, there could be a delay perceived as a result of intervening routers, TCP buffers etc.; in addition, the time-delay may as well prevail as a result of SS technique adopted Relevant heuristics are as follows:

While the SS technique renders large BW operations, the local area (mostly indoor) ambient would affect signal transmissions between hosts as a result of various underlying coexisting EM RF links; and, such coexisting (ISM-band) devices (like non-(Wi-Fi), Bluetooth^{TM}, Zigbee^{TM} etc.) in the operating environment may cause signal impairment at the receiving node [5–7] as a result of EM interference (EMI) issues. For robust performance, therefore, it is necessary to estimate the maximum possible separation between hosts in the WLAN-based OS migration (in the event of such interference being experienced).

Hence, in WLAN perspective, the host-to-host separation distance in OS migration has to be estimated in terms of WLAN operation constrained by indoor wireless propagation considerations as well as other delay implications arising from SS technique adopted.

The objective of this study is therefore to develop, (i) an analytical model that determines the permissible host-to-host separation distance in OS migrations; and (ii) indicate mitigation possibilities for improved performance integrity of such OS migration efforts deployed in WLAN environment. The following sections describe the strategies conceived thereof.

4. Optimum host-to-host separation in OS migration operations in WLAN contexts

The wireless performance of WLAN is decided by (or could be hampered as a result of) harsh indoor EM ambient set up by the mutual EMI of RF signals transmitted from various systems that are co-located in the same premises and operated at the same frequency band (namely, ISM band). For example, consider a WLAN that operates along with Wi-Fi^{TM} Bluetooth^{TM} and/or ZigBee^{TM} systems all co-located in the indoor premises. They all operate in the ISM-band of 2.45 GHz. In this confined RF spectrum, in spite of distinct modulations used, there is a possibility of mutual interference when such systems coexist and operate in the same locale. As such, the RF signal of any of the co-located system may face interference-related deterioration in its functions. Thus, the overall performance of

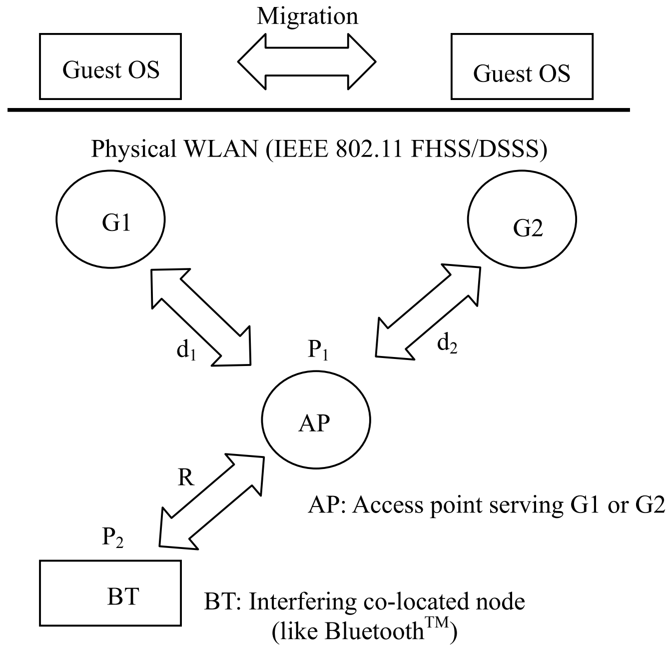

Figure 2: An interference scenario of OS migration set on a WLAN-link. The RF interference (RFI) is presumably caused by an IEEE 802.11 FHSS/DSSS device (like Bluetooth™) communication. R, d_1, and d_2 are node separations (in meter) as shown, P_1 and P_2 are transmitted power levels of the units.

the WLAN being present in that location may also be impaired. Relevant (performance) parameters that could possibly be affected are as follows:

- Symmetric throughput (in bps) performance *versus* bit error rate (BER),
- BER *versus* radio-link distance under LoS and non-LoS situations,
- Packet error rate (PER) *versus* link distance.

The above considerations are analytically modeled in the following sections.

Suppose P_1 and P_2 in Fig. 2 denote transmitted powers at the interferer and the victim device respectively and α is the distance power-gradient exponent decided by EM ambient of WLAN operation. Further, it is also assumed that the victim device (like an access-point router) operating at transmitter power level P_2 communicates with active hosts G1 or G2 located at the distances of d_1 and d_2 respectively as shown. Hence, with reference to the interference scenario of OS migration on a WLAN-link set by an IEEE 802.11 FHSS/DSSS (like Bluetooth™) communication with R, d_1 and d_2 being node separations (in meter) as illustrated in Fig. 2, relevant signal-to-interference ratio (SIR) can be specified by

$$\mathrm{SIR} = (P_1 d^{-\alpha})/(P_2 R^{-\alpha}), \tag{1}$$

where d represents either d_1 or d_2 in Fig. 2.

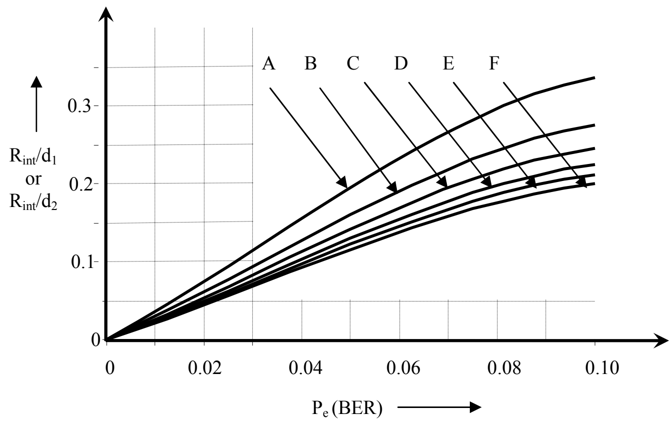

Figure 3: R_{int} (normalized with respect to d_1 or d_2) *versus* the probability of bit-error (BER) for a set of parametric values, B_1/B_2. The graphs shown correspond to the following sets: B_1/B_2 = {1/100, 1/200, 1/300, 1/400, 1/500, 1/600}≡ {A, B, C, D, E, F}.

5. RFI-specific performance analysis of OS migration on a WLAN-link

Given an acceptable level of SIR, the corresponding range of interference, namely, R_{int}, (which denotes the range below which the interferer would kill the packets of the victim device) is given by [8]

$$R_{int}/d_{1 \text{ or } 2} = [\mathrm{SIR}_{min} \times (P_1/P_2) \times (B_1/B_2) \times (E_b/N_o)]^{1/\alpha}, \tag{2}$$

where B_1 and B_2 are spreading-bandwidths of the interferer and the victim device, respectively. Further, SIR_{min} depicts the minimum allowable SIR for no packet-losses due to interference-dictated BER. In the IEEE 802.11 ambient supporting devices that use GFSK modulation plus FHSS-specific Gaussian filter implementation the BER or probability of bit-error (P_e) can be specified as follows [9]:

$$P_e \approx 0.45 \times (E_b/N_o)^{-0.65}, \tag{3}$$

where E_b/N_o denotes the (bit-energy)-to-(noise spectral density) ratio. Further, for FHSS/GFSK operation, the time-bandwidth product (BT_b) is 0.5 (with a pulse-duration T_b through the Gaussian filter of bandwidth B with the corresponding modulation index h constrained by $0.28 \leq h \leq 0.35$ [10].

6. Results

For the scenario illustrated in Fig. 2, a typical set of data can be considered as follows: SIR_{min} = 10 dB (or a ratio of 10); P_1/P_2 = (1 mW/100 mW), α = 3.5 (for indoor WLAN ambient). Hence, for a sample set of B_1/B_2 (<1) ratios, namely, {1/100, 1/200, 1/300, 1/400, 1/500, 1/600}, the computed results of Eq. (2) are plotted as shown in Fig. 3.

Though the data used in aforesaid computations are hypothetical, the results obtained indicate the extent and nature of interferer influence on the physical separation of the hosts (of the OS migration set-up with respect to a common node such as the access point, AP) as a function of the BER.

In spite of the model as above being simple, it can be further expanded to include other physical-layer considerations and native protocols involved. For example, the deployment of wireless networks in OS migration settings could be hampered by the unpredictable wireless-link (EM-propagation dictated) performance in the premises where the wireless connectivity is established. As such, for the purpose of extracting and assessing OS migration performance across IEEE 802.15.4-compliant wireless networks, more exact modeling has to be done towards knowing the relationship between host-interferer separation and various communication properties (such as packet reception rate) under different wireless network feature configurations (like output power level, packet size, channel asymmetry, channel propagation models (dynamic in space and/or time), antenna features, any diversity employed etc.) [11].

Further, apart from considering a device like Bluetooth™ or ZigBee™ posing relatively a smaller BW in comparison with that of an OS migration host (that is, B_1/B_2 <<1 as in Fig. 3), the problem under study can be expanded to include situations where B_1/B_2 tends to be larger than 1. This can happen when two (or more) independent OS-migration host-pairs coexist in a given IEEE 802.11-compliant FHSS/DSSS wireless operation done *via* WLAN implementation. Relevant considerations can be studied with the computed results from Eq. (2) presented in Fig. 4. The results of Figs. 3 and 4 are discussed in the following section.

7. Inferential remarks

Considering the results presented in Figs. 3 and 4, the salient observations that can be made are as follows:

i. The R_{int} is essentially decided by B_1/B_2 ratio and the prescription on BER.

ii. Referring to Fig. 3, a large value of host BW (B_2) relative to that of the interferer (as for example in graph F, with B_1/B_2=1/600) can permit a closer host-to-interferer separation for a given prescription on BER value. This is because larger information BW (of the host) will not be significantly influenced by any low-BW spectral spill-over from the interferer (under IEEE 802.11-compliant FHSS/DSSS wireless operation *via* WLAN implementation).

iii. Considering Fig. 4, the observation (ii) can be further visualized with B_1/B_2 being larger than 1; that is, the interferer BW is exceeding that of the host communication BW (B_1/B_2 ≥ or >>1). This can happen, as mentioned earlier, whenever two independent OS migration operations, for example, are concurrently allowed to coexist in the same WLAN premises. Due to competitive spectral spill-over arising thereof, for any given B_1/B_2 (>1) ratio, corresponding R_{int} would increase if low BER is desired. Necessary mitigation efforts are then needed. It is suggested here to implement diversity methods as suggested by Neelakanta et al. in [12–14].

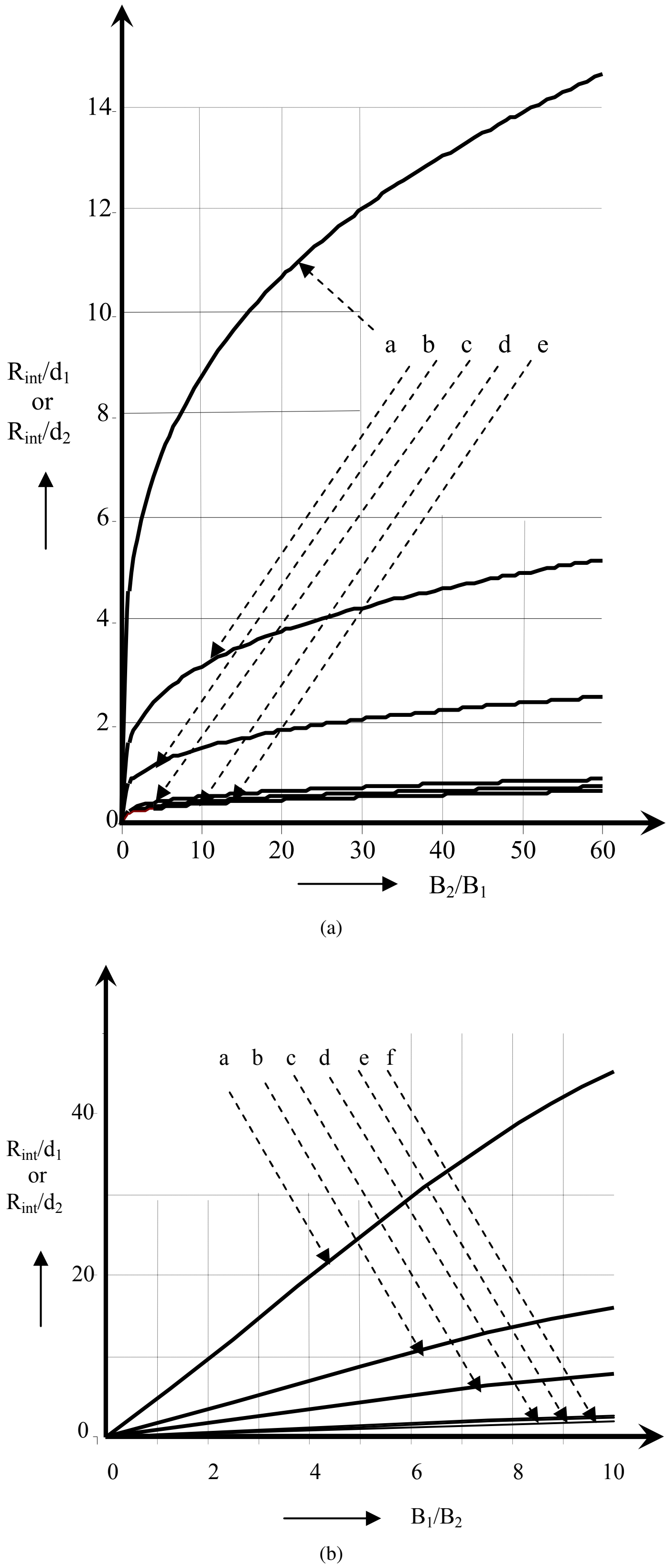

Figure 4: B_1/B_2 ratio (>1) *versus* R_{int} (normalized with respect to d_1 or d_2) for a set of parametric values of the probability of bit-error (BER). The graphs shown correspond to P_e = {0.0001, 0.0010, 0.0050, 0.0500, 0.0750, 0.1000}≡ {a, b, c, d, e, f}; (a) B_1/B_2 ratio over a range of 0 to 600, (b) B_1/B_2 ratio over a range of 0 to 10.

8. Closure

This paper is a preliminary exercise on the topic presented as regard to OS migration versus WLAN considerations. To the best of authors' knowledge no such prior study is reported in the literature. The results shown indicate more scope for advanced research, for example, to exercise better efforts in elaborating Eq. (2) so as to include both physical and higher layer considerations. They are open-questions for further research.

In enabling OS migration in the indoor WLAN environment, not only the associated RF-link implications discussed in this study are crucial, but also an overall assurance on information security is necessary. Apart from wireless specific mitigations indicated earlier, as observed in [7], data centers wherein OS teleportation is implemented, a systematic shielding efforts are required [15–17].

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