### Carl A. Waldspurger Memory Resource Management in VMware ESX Server In Proc. Fifth Symposium on Operating Systems Design and Implementation (OSDI ’02), Dec. 2002

1. What are the motivations given in this paper for using Virtual Machines? What new requirements does VMware have that Disco did not?
2. Review: Draw a diagram showing how physical memory is mapped to machine memory. What does the pmap data structure do?
3. What is one problem that server consolidation introduces? One solution is to have the VMM move one of the VM pages to a swap area on disk. What are the problems with this?
4. Observation: Can’t change OS, but can load a new driver into it. When the VMM server wants to reclaim memory, what does it do? How will the guest OS respond if memory is plentiful? If memory is scarce? What information does the VMM server receive? How can the server ensure that the guest does not touch the returned page?
5. What does Figure 2 show?
6. What is one opportunity that server consolidation introduces? How did Disco previously find these opportunities?
7. How does VMware determine if multiple pages can be shared? What are the advantages of this general approach? How is hashing used to check with pages that have been marked copy-on-write? What happens if a match is found? What happens if a match is not found?
8. How much memory savings do these techniques lead to?
9. What is an additional requirement for competing guests in a consolidated environment? What is a basic approach for giving each guest its fair share of memory? Which guest will have a page revoked? (What is the formula?)
10. Why doesn’t the completely fair approach lead to the best aggregate, system-wide performance? How is the shares-per-page formula modified? What does the server need to know to apply this formula?
11. How is the amount of idle memory in a guest obtained without modifying the guest?
12. What do Figures 6 and 7 show?
13. What memory parameters need to be set by a system administrator for each VM? How much disk swap space must be reserved for each VM?
14. How does the ESX server change its policies as the amount of free memory in the system changes? For example, what if there is more than 6% (high) free mem? Below (soft) 4%? Below (hard) 2%? Below (low) 1% What optimization helps a lot when first booting many guests?
15. Conclusions?