K-Board v2: over ProcFS

운영체제 3분반

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3-1. 결론

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**과제 개요.**

과제 1에서 수행했던 것과 마찬가지로, Ring Buffer를 통한 클립보드 구현임에는 변화가 없습니다.다만, Proc 파일시스템을 통해 커널에 접근하므로, 커널 모듈 프로그래밍의 틀을 가지고 있다는 점이 가장 큰 차이입니다.

또한, Reader/Writer 문제를 검증함에 있어 Enqueue, Dequeue 작업을 Writer로 고려합니다.

RingBuffer 내 임의의 값을 읽는 Read 작업과 함께 Reader/Writer 문제의 Solution들의 구현과, 각각의 문제점을 확인합니다.

1. **Kboard\_copy, Kboard\_paste, Kboard\_read**
   1. **수행결과**

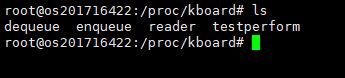


그림 1 생성결과

모듈 적재 후, /proc/kboard/ 디렉터리의 내용입니다.

Writer역할의 Enqueue, Dequeue, Reader 역할의 reader, 동기화 테스트 결과 출력용인 testperform이 생성됩니다.

기본 Kboard Clip보드 수행결과 즉, 테스트입니다.

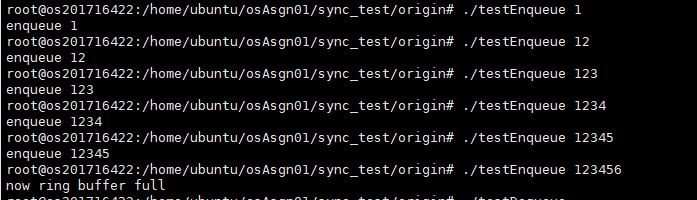


그림 2 Enqueue 작업

그림1에서 6개의 데이터를 삽입해줍니다. 6번째 데이터 삽입에서는 Ring buffer가 가득 찼다는 메시지를 정상적으로 출력해줍니다. **(Stack Full)**

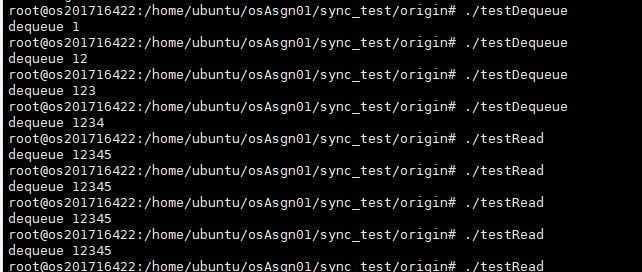


그림 3 Dequeue 및 Read작업

위 작업에서는 추가한 데이터를 붙여넣기 합니다. 데이터가 1개 남았을 때, Read작업을 2회 수행하여 Read작업에서는 남아있는 데이터가 삭제되지 않고 읽기작업만 수행됨을 보여줍니다.

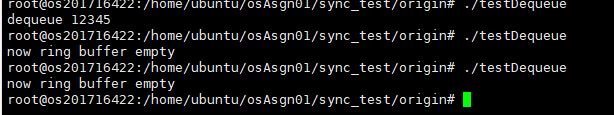


그림 4 Dequeue작업

마지막으로 남은 데이터를 Dequeue해주어, 버퍼가 비어 있을 때, 적절한 에러 처리를 해주는지 테스트하였습니다.

* 1. **핵심 소스코드**

기본 clip 기능구현에 있어 핵심적인 소스코드입니다.

템플릿코드로 제공된 부분은 특별한 변경 없이 사용하여, 추가적으로 설명하지 않았습니다.

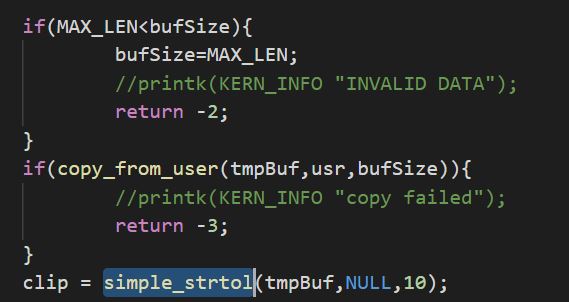


그림 5 do\_kboard\_enqueue

Enqueue작업(write 시스템콜, echo) 수행 시 호출되는 do\_kboard\_enqueue 함수의 일부입니다. 유저 테이터인 write의 인자를 tmpBuf에 저장해, 문자열길이 검증을 수행합니다.

커널 내 RingBuffer에 기록하는 작업을 수행하기 위해 값을 long 형태로 변환합니다.

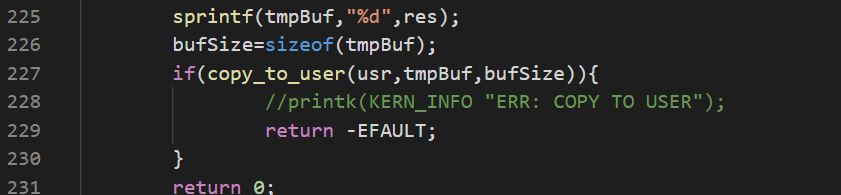


그림 6 do\_kboard\_read

Read작업을 수행하는 do\_kboard\_read 함수에서는 커널 내부 변수인 RingBuffer 내의 값을 유저영역에 전달해줍니다. do\_kboard\_dequeue에서도 비슷한 동작을 수행합니다

1. **동기화 문제 해결**

수업시간에 다룬 Reader/Writer 문제에서 Solution 1,2,3들을 구현해보며 발생한 각각의 문제점들을 확인하고 고쳐 나가는 방법으로 과제를 수행했습니다.

**2-1. 동기화 문제 해결 및 수행결과**

Solution 1에서는 Writer Starvation이 발생하지만 Solution2방법으로 해결합니다.

하지만 Solution2에서는 Reader Starvation이 발생하고, Solution 1,2의 문제점들을 균형 잡힌 방향으로 해결하는 Solution3까지 구현합니다.

**2-1-1. Solution 1**

![스크린샷, 텍스트이(가) 표시된 사진

자동 생성된 설명](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAeAB4AAD/4RD0RXhpZgAATU0AKgAAAAgABAE7AAIAAAAOAAAISodpAAQAAAABAAAIWJydAAEAAAAcAAAQ0OocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAE15dW5nIEt5dSBMRUUAAAWQAwACAAAAFAAAEKaQBAACAAAAFAAAELqSkQACAAAAAzA1AACSkgACAAAAAzA1AADqHAAHAAAIDAAACJoAAAAAHOoAAAAIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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mp6nYalr2m2V9e/apNPjtoZobgNtLo8bSBVO7cA2G4I4HSs/wAP30HiK68TaRDpF5HZ6w4vIrfSo1mmtWjkJRUjJXzFAkIKgg45HSuEopJK1v6/rQbbZ6r4q1jTfDccejCO7Eh8KjTjHIF8yGZrjzf3oB+Q7RkqMlSwHOM1z2neN7bTT4SeO2llOjQ3EN3G2FEqSyOWCHJ/gkI5A59RXF0Ubu7/AK3/AM2Lpb+tkv0On1fWtHi8Kp4f8Om+mt3vjez3N7EkTkhdiIEVmGAC2WzyT0GKs69qnhq88F6TpWnX2qvdaWZihuNOjjSbzXVjkidiuAD2bPtXH0UAdH4v1azujp2k6NL52maTbCGGUIU8+RvmllwQCNznAzzhVrasPG9jZ+D7jS7u81bVUlsWt4tMvoY3t7aUgASxzFiyheoVUXsM964Kijo13BaNPsel/Di/l0Twnreq6tZNJpVmUu9PllBCHUVysaoSMMcOSwHICg1yc/iCG48CwaRIJ3vU1WW+klYAqyvGi9c53ZUk8fjWBRTvrf0/B3/RfJIFp/X9f0zvdR8a6PrGteKY7yC9i0rXpo50mjRWnt3jJKnYWCsDuYFdw65zxXGaiunreFdIkuZbZVAEl0io7nudqlgo9tx+tVa0NK1/WdD83+xNWvtO87HmfZLl4t+M4ztIzjJ/OpSSVgM8HBrs9e8VaXc+M7bxbo7Xn9oLcwXMllc2yCJGjC52yrISwLL3ReD7c4Op+KPEGtWottY1zUtQgVg4iuruSVQwyM4YkZ5PPvWVVJtO66CaTVjvfEfjiy1DTNUi0y4nRtUYebb/ANi2VttXzA+1p4xvl5A5wmSMn0o1fxvY3vgy70iW81bW5ZvLFqdVhjzp4VtzFJgzO+R8uMIME8dq4KipskrFXd7nT6brGjTeB5PD+sy31q6X/wBthntLZJw2Y9hRlaRMdAcgnvxUZ1azsPh6NK0+YSXuqXPnagQhHlRx8RRZI5ySznHH3R1BrnKKb1v52/D/AIZCWh2PgjxXB4cQ+fq+s2iGcPNZ2sEdxb3acfK6SOoU8EbsNwenHLLPxNo848SWOoWc+nabrU6XEQsUWVrNkdmRQjFAy4cr1XsfauRooeu/9f1YNlY6nV/FNpJrmgy6TBMbLQoYYYPtOFkn2SGRmYLkLlmPAJwMcmqvia60LVPFM2oaddaittfXLz3Cz2iB7fe+SExIRJjJ67M4HSsCijzfn+O4f8D8NjudZ8R+HZr7w/d6ZPfztpdrDYyxX2k27JJEu7c4DSyKWw3ClcDru4qTxp8SW8S6W1laWtvCk93PPcbtOt1baWAhCsFLArGoBbIJyRkgVwVFD13/AKuC02CvquvlStX/AISrxD/0HdT/APAyT/GvEzXLZ4/k5ZW5b/jb/I+dzvKKmZ+z5JKPLffzt/kHir/kcdZ/6/5//RjVlU6WWSeZ5p5GklkYs7u2WYnkkk9TTa9inHkgo9ke9Sg6dOMH0SQUUUVZoFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQB9D/tWf8AMpf7l1/7Rr54r6H/AGrP+ZS/3Lr/ANo188UAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQB//9k=)

그림 7 Solution1 Test1

위 그림에서는 5초간, write작업인 Dequeue,Enqueue작업을 각각 3개씩 6개 프로세스가 시행하고,

read작업을 6개 시행한 결과 몇번의 작업이 수행되었는지 보여줍니다. 그 결과, 에상대로 Read 작업이 더 많이 수행되었습니다.

하지만, 이정도로 writer starvation이라고 판단하기 힘들어, 더 많은 프로세스를 가동시킨 결과, 아래와 같은 결과가 나왔습니다.

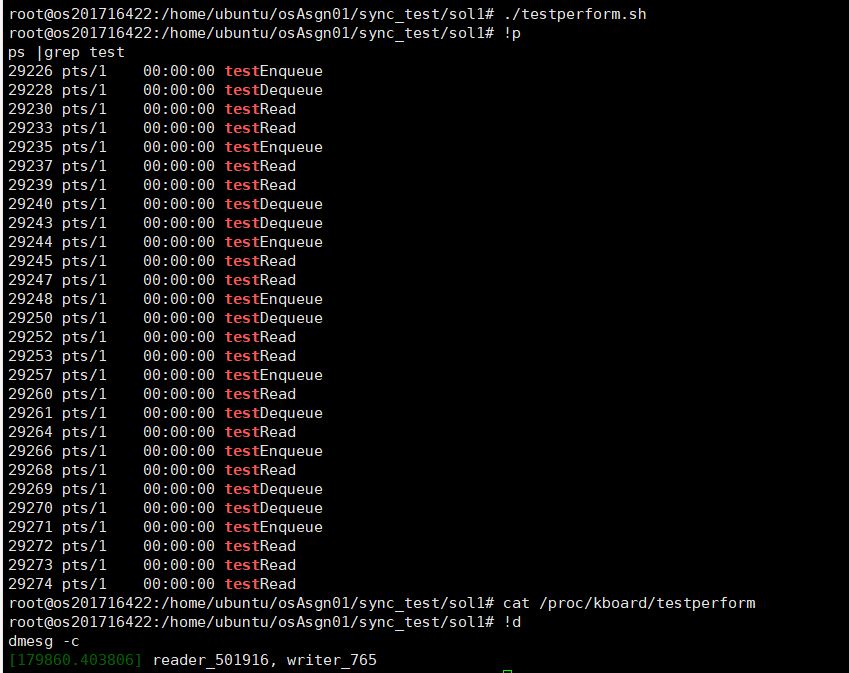


그림 8 Solution1 Test2

(enqueue, dequeue, read 각각 7,7, 14개 프로세스)

50000: 700 >> 이정도로 starvation이라고 판단하기는 애매할 수 있지만, 프로세스 수를 늘려가며 테스트한 결과, 60000 : 190정도의 차이까지 벌어졌습니다.

**2-1-2. Solution 2**

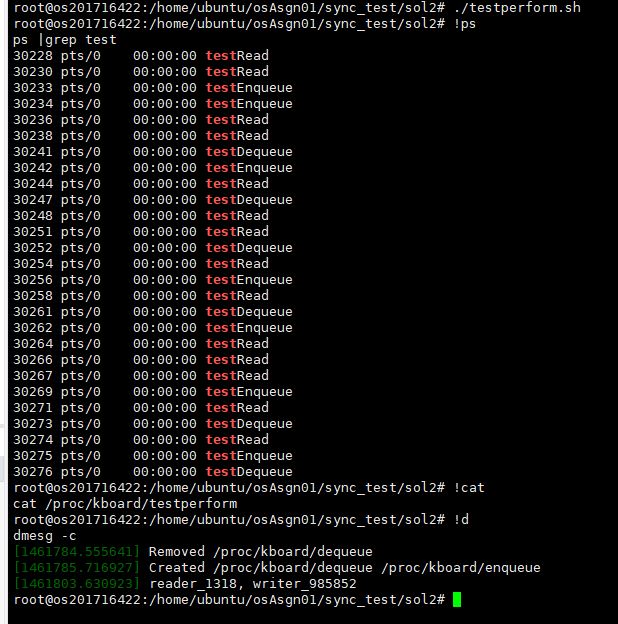


그림 9 Solution2 Test

Solution 2 에서는 바로 enqueue, dequeue, read 각각 7,7, 14개 프로세스를 실행한 결과

Reader : Writer🡺 약 1:700 으로, 심각한 Starvation 상태가 일어났습니다.

**2-1-3 Solution 3**

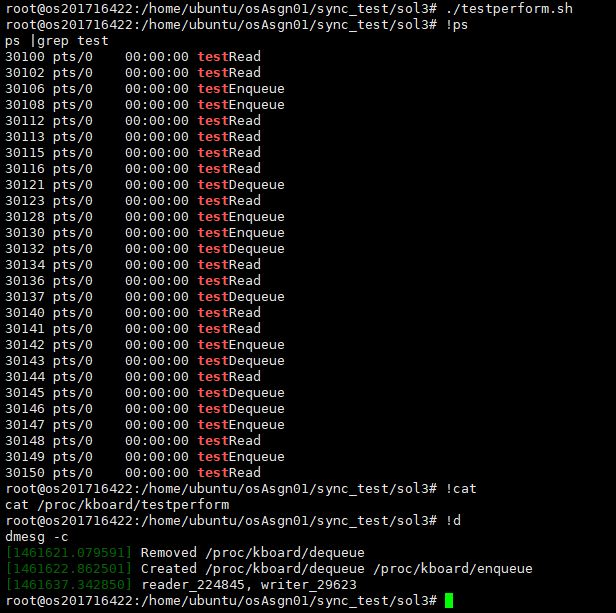


그림 10 Solutio3 Test

Solution 3에서 역시 enqueue, dequeue, read 각각 7,7, 14개 프로세스를 실행시켰습니다.

Writer의 수행이 더 적긴 하지만, 위의 솔루션들에 비해 기아상태라고 불릴만 한 정도는 아님을 확인했습니다.

1. **결론**

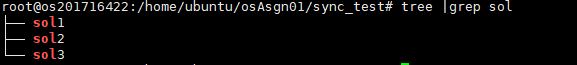
**3-1. 결론**

2-1 그림 7,8,9에서의 결과를 아래 표로 정리했습니다.

|  |  |  |  |
| --- | --- | --- | --- |
| 솔루션 | Reader | Writer | 비율 |
| Sol1 | 501916 | 765 | 656 : 1 |
| Sol2 | 1318 | 985852 | 1 : 747 |
| Sol3 | 224845 | 29623 | 7 : 1 |

세 솔루션 버전 모두 Reader, Writer를 14개 : 14개 동일하게 실행시켰음에도 불구하고, 실행 비율 면에서 큰 차이를 보였습니다.

**3-2. 실행방법**



첨부한 소스코드는 위와 같은 디렉터리 구조를 가지고있습니다. 솔루션별로 효과적인 분리를 위해 제출 양식과 다른 형식으로 제출하는 점 양해 부탁드립니다.

1. sol1,sol2,sol3 디렉터리 내에는 각각 해당하는 솔루션의 모듈 파일이 있어, 각각을 make 해줍니다. 이후 모듈을 적재해줍니다.
2. 각 디렉터리에서 testperform.sh 를 통해 실행할 프로세스 수 조정 및 실행
3. ps |grep test 로 실행중인 프로세스 확인
4. cat /proc/kboard/testperform 으로 실행결과 커널메시지 출력
5. dmesg 로 결과 확인

동기화 확인 외에 기본기능 테스트를 하실 경우, 솔루션들 중, 아무 모듈이나 적재하신 후,

cat, echo를 사용하시면 됩니다.

**3-3. 여려웠던 점 및 해결방안**

1. 커널 내에서 데이터를 처리 할 때, 유저 프로그램에서 사용하는 라이브러리를 사용하지 못하는 점이 번거로웠습니다. 이에, sprintf, simple\_strtol, get\_random\_bytes 등의 커널 라이브러리들을 활용하여 해결했습니다.
2. 템플릿코드(mod\_proc.c) 에서 사용하는 list 구조체를 사용하고자 했으나, 사용방법을 익히기 어려워, 과제1에서 사용한 그대로, 배열을 이용해 ring buffer를 구현하였습니다.
3. 동기화 처리 과정을 이해하기 힘들었지만, PPT와 교재를 통해 충분히 학습 후 적용할 수 있었습니다.